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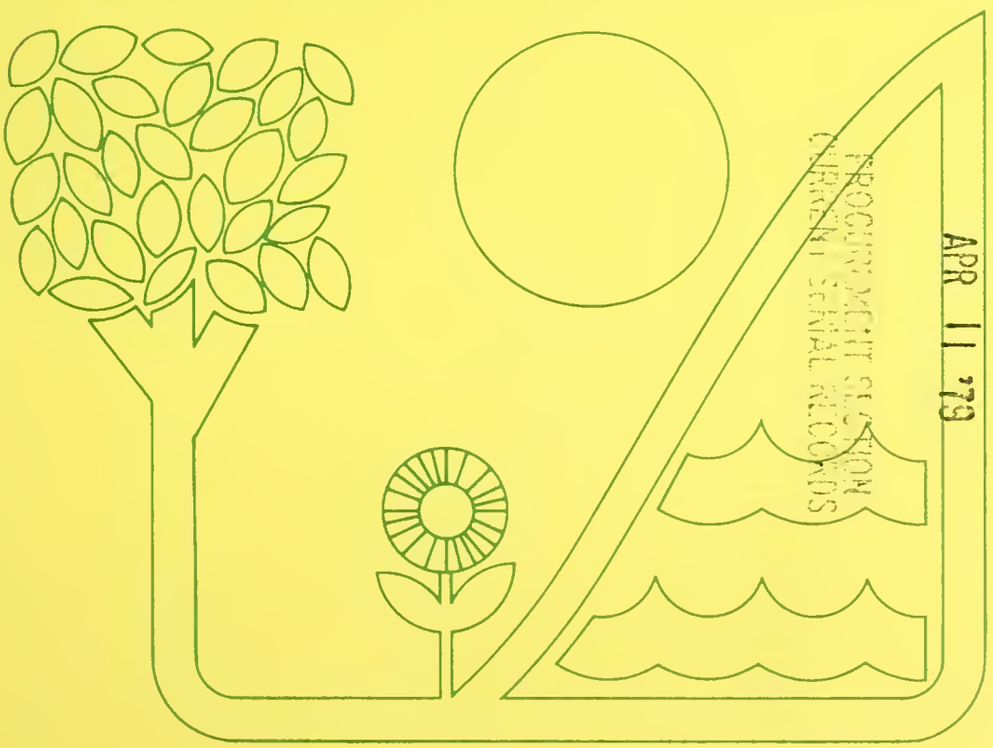

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# RESOURCES OF ROCKY MOUNTAIN STATES AND COAL DEVELOPMENT

April 1978

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ABSTRACT

Surface and underground mining of coal and coal-fired electric power generation in the Rocky Mountain States (RM) are developing rapidly. There is a need to analyze the cumulative effects of greatly expanded energy development in this region. USDA economists are undertaking an integrated assessment of how alternative patterns of coal development and use might affect agriculture, rural people and communities, and the availability and use of land and water. This report is one of a series and is primarily descriptive, laying groundwork for analysis to be reported subsequently.

Fifteen RM sub-regions called Coal Production Areas (CPA) are delineated. These include all the RM areas containing commercially recoverable coal reserves, although significant coal mining is not yet occurring in all the CPA's.

Coal-related activity in seven of these CPA's grew considerably starting in the early 1970's. In these areas, employment and population expanded rapidly. Previous outmigration of population from these CPA's reversed, in general, in the early 1970's to become a net inmigration. The greater employment opportunities associated with coal development are partly responsible.

The RM contains only 5 percent of U.S. coal reserves, but this comes to about 23.7 billion tons. Of that amount, 3.7 billion tons are surface mineable, enough to allow major mining activity for a long time. Underground mining of deeply-buried reserves is also developing, however, particularly in some of the 14.5 billion-ton reserves of excellent

quality, highly-ranked bituminous coal. The 5.4 billion ton deep-mineable reserves of lower-energy sub-bituminous coal are much less likely to be developed soon. About three-fourths of RM coal is relatively low in sulfur content, making it desirable for use by electric utilities in meeting air quality and emission standards of States and the Federal Government.

Coal production in the RM has risen from about 9 million tons per year in 1960 to 19 million in 1970 and 37 million in 1976. Two-thirds of this amount is now mined by surface methods, whose share is increasing. About two-thirds of the coal is burned by electric power plants in the RM itself, although the proportion of coal which is being shipped outside the RM region has been rising.

Only 1/10 of 1 percent of the RM land surface is underlain by surface mineable coal reserves, and less than one percent by all coal reserves. For all the CPA's, the Federal Government is the dominant owner of land, with 41 percent of total acreage. Private owners have 31 percent, Indians 22 percent, States 6 percent. Of the total land area, 53 percent is in farms and ranches, although almost all of this is pasture and range. There are 16,000 farms and ranches. Most of the small amount of cropland is irrigated, but almost all of the irrigated land is used to support livestock ranching in some way, such as by producing feedgrains or hay for irrigated pasture. Sales of livestock account for most of farm income.

Irrigation accounts for 60 percent of surface water use in the Upper Colorado Basin, about the same in the Lower Colorado. Assessing the availability of water for future energy development in the RM is extremely complex, but, in general, there is very little Colorado River water available except through diversion from current uses, such as agriculture. Alternatives need to be explored for obtaining water for energy development from increased use of groundwater, as well as from more efficient water use in both farming and energy industries.

NOTICE AND DISCLAIMER

This document is a preliminary draft. It has not been formally released by the U.S. Environmental Protection Agency nor the Department of Agriculture and should not be construed to represent policy of either EPA or USDA. The contents of this report reflect the views of the research team only. It is being circulated for comments on its technical merits and policy implications.

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In addition, other individuals are engaged in related work on this project, and their contributions will appear in subsequent reports. The editorial assistance of John C. Roney and typing by Angelle Bratcher, Marcia Shambarger Diana Charles and Jean Stidham are gratefully acknowledged.

Figure 1. Technician examining land being reclaimed, Utah International Mine, Fruitland, New Mexico

Figure 2. Four Corners Power Plant, Fruitland, NM.

# SUMMARY


## PEOPLE

During 1970-74, the previous population trend of net outmigration from most Coal Production Areas (CPA) of the Rocky Mountain region (RM) reversed, becoming a net inflow. The reversal was prompted partly by new jobs related to increased coal mining and coal use, and the closely associated industry of contract construction. However, CPA CO-7 is an exception and does not fit the above pattern for two main reasons: (1) It includes suburban areas of Denver plus Colorado Springs, whose populations have been growing anyway; and (2) There is relatively little coal mining in CO-7, although there are large coal reserves. Still, these are deeply-buried, low-energy, sub-bituminous reserves, unlikely to be developed soon by conventional underground mining. Even though coal development, as yet, has had little impact in CO-7, in the other RM CPA's mining employment during 1970-74 increased twice as much (in percentages) as the average for the U.S. as a whole.

About one-fifth of the RM's population in CPA's belonged to one of three minority groups: Indians, Spanish Americans, or Blacks. In general, the Indian population in CPA's has characteristics differing considerably from U.S. averages--younger, more fertile, lower school enrollment, fewer school years completed, lower labor force participation, lower incomes, and higher incidence of poverty. Therefore, where Indians are affected by coal development, impacts are likely to be stronger than on non-minority populations.

The surge of coal production in the RM in the early 1970's brought renewed vitality to small towns. Although population increases from 1970 to 1974 in these towns were not large in absolute numbers, relative impacts were substantial and many towns of less than 500 in 1970 were affected.

COAL

The RM contains almost 6 percent of U.S. coal reserves, a percentage adjusted to a common heat-value basis to compensate for different energy values per ton among coals. While this is a low percentage, total RM reserves come to 23.7 billion tons--enough to last 640 years at the 1976 rate of production. This was 37 million tons per year, up sharply from the 13 million tons of 1965.

Only 16 percent of the RM reserves are surface mineable (strippable). Yet, two-thirds of 1976 production was by surface mining. Almost all this output is from new large surface mines each producing over 500,000 tons per year.

Of the strippable reserves, almost two-thirds are in New Mexico, Colorado having most of the remainder. Of the deep mineable bituminous reserves, Colorado has almost two-thirds, while Utah has most of the rest. Although only bituminous coal (of higher heat value than subbituminous) is now being mined by underground methods, both subbituminous and bituminous are being surface mined.

About three-fourths of all RM reserves are estimated to contain a "relatively low" amount of sulfur (0.6 lb. or less per million BTU), a major

contributor to air pollution through sulfur dioxide emissions upon combustion. The 0.6 lb amount was the 1971 standard under the Clean Air Act. It was tightened in 1977 for regulatory purposes, but the 1971 standard can still be used as a break-point to characterize the sulfur content of reserves. The relatively low sulfur content of most of New Mexico's strippable coal deposits, for example, probably spurred coal output in that State significantly during the early and mid-1970's.

Also spurring production was relatively high coal output per acre, permitting surface mines to be large scale and to achieve economies of size. Thus, average mining costs per ton of coal produced are relatively low. Strippable reserve tonnage per acre is one and one half to two times that of the Appalachian and Midwest amounts, although much less than half that of the Northern Great Plains.

However, only one-third of the RM coal output is shipped outside that region, since, in competing for sales in distant markets in the Midwest, added transportation costs can offset any mine-mouth cost advantage which RM coal might have. Most of the RM coal used within the region goes to utilities to generate electric power. Several new coal-fired electric plants over 100 megawatts (MW) in size were brought on-line in the RM since 1970. As of 1976, there were 21 electric plants of all sizes in the RM, with a total capacity of 7,956 MW. For the period through 1984, 24 new coalfired plants are under construction, planned or proposed. The total capacity of these is 8,613 MW. Assuming all are completed, demand for electricity coal in the RM could rise from the 21 million tons of 1975, to 55 million tons by 1984.

LAND

The 15 CPA's of the RM region encompass 91 million acres out of the 272 million acre total area of the region. However, only 2/3 of 1 percent of the RM's total land area is underlain by coal reserves (surface mineable plus deep), although surface mineable coal alone is present under only 7/100 of 1 percent of that total acreage. In absolute numbers, strippable coal underlies 186,000 acres in the RM, deep mineable coal reserves another 1.5 million acres.

Slightly more than 41 percent of the land in CPA's is owned by the Federal Government, 31 percent by private parties, 22 percent by Indians, and 6 percent by States. Ownership patterns vary considerably, however, among CPA's. In NM-1, AZ-1 and NM-2, where there is much active coal mining, half or more of the land is Indian-owned. But, in the Utah CPA's, CO-1, CO-2, CO-4 and NM-4, most of the land is federally-owned. State land is about 10 percent in CO-2 and NM-4, while private land predominates only in CO-6, CO-7, and NM-3.

Separation of coal ownership from land surface ownership is common in the case of privately-owned land. Here, a complex patchwork of mineral ownership exists. But, in general, for Federal, State, and Indian land, surface and mineral rights are owned together.

Of the 91 million acre land area of the CPA's, 48 million acres are classified as "in farms," although most of these are livestock ranches. More than 90 percent of the land in these ranches is pasture and range.

Only 4 percent is cropland. AZ-1 has the largest agricultural area of the CPA's, although most of it is low carrying capacity rangeland. In terms of productive capacity, CO-7 dominates, having more cropland, harvested crops, and greater farm income than any other CPA.

There is some irrigated land in each of the CPA's, although more than half is in CO-4 and CO-7. Irrigated land is closely associated with livestock raising, most of the land being used as irrigated pasture or harvested for feed or forage. Livestock raising accounts for three-fourths of gross farm income.

The 15-CPA area contains 16,000 farms and ranches, classified into essentially three types: (1) "Abnormal" farms, usually Indian reservations or grazing associations, very large in size, often reaching or exceeding 350,000 acres; (2) Farms grossing over $2,500 per year, but not reservations nor associations. These are the "normal" sized ranches; this group averages almost 2,200 acres in size; (3) Farms grossing less than $2,500 per year. These are very small.

In most of the RM CPA's, crops and livestock tend to be raised using a relatively large land input per unit of output. In general, therefore, RM agriculture may be thought of as "extensive." Exceptions are irrigated farming of high value crops, and cattle feedlot operations. Feedlots are common in CO-7, which has 71 animal units for 1,000 acres, but other CPA's range downwards from 26 units per 1,000 acres. Since agriculture uses land extensively,

relatively little agricultural activity in total would be permanently or even temporarily disrupted by coal surface mining. For each million tons of strippable coal reserves, the potential for land disturbance would range from 32 acres in CO-2 to 153 acres in UT-1. At this disturbance rate, if cumulative RM coal production over the next 25 years were to reach 1.6 billion tons, about 118,000 acres (cumulative) would have been disturbed.

While environmental and reclamation problems associated with this disturbance could be severe, the land at risk would be equivalent to only 41 farms of average size. The disruption could be very great for the ranches involved, but would not materially affect total agricultural production.

The situation could differ, however, if irrigated cropland (largely a livestock feed base) were to lose large amounts of its water to energy development such as new coal-fired power plants. Loss of irrigation water could greatly increase pressure on dryland grazing as a substitute for irrigated hay crops no longer available. Consequently, livestock numbers could be sharply or moderately reduced, depending on the amounts of water diverted to energy uses.

## WATER

Assessing the amount of water available for energy development in the RM region requires an appraisal of the water resource itself, especially amount and location, as well as a look at the current and projected water depletions for various energy and non-energy uses.

The Colorado River Basin provides the largest quantity of surface water in the RM. Although the major portion of supplies comes from the Upper Basin, the major consumption occurs in the Lower Basin. Even without adding new depletions for energy use, projections of current kinds of depletions, (including irrigated agriculture, industrial and urban) show that the Basin would be using all its water not long after 1980. It is highly likely that expanded levels of energy development cannot be supported by Colorado River water except at the expense of other uses or by much greater efficiency in all water uses.

Groundwater resources could be exploited further, but only at the cost of mining this resource generally throughout the RM. Groundwater mining is already occurring in the Gila Subregion (Arizona). Groundwater supplies from well-defined, known sources, however, probably could not be relied upon as the sole source of supplies for energy facilities. Groundwater from deep aquifers might be better suited as a dependable, though ultimately exhaustible, supply for energy conversion, but data on the size of deep aquifer resources is very limited.

In all the Rocky Mountain region, with the exception of the North Platte Basin, water is scarce even under current demand conditions. Unless the technology of water use becomes more efficient, additional large scale coal development will result in the diversion of water from

current uses, most likely from irrigated agriculture. If energy companies were to purchase and exercise large numbers of water rights in the Colorado River Basin, not only agriculture but also the communities which service the agriculture sector could be drastically affected.

Finally, an important dimension of the water supply picture is the complex web of claims and rights to use Colorado River water. Rights to this water were allocated to several states in the 1922 Colorado River Compact. Since 1922, regional development patterns have resulted in a far greater use of water in the lower reaches of the Colorado River than in the upper reaches, where most of the water originates. Continuing development in the Upper Colorado River Basin and the consequent exercising of water rights in that region may very likely result in inter-regional or inter-state legal disputes. Moreover, a recent U.S.-Mexican treaty entitles Mexico to certain amounts of Colorado River water of a specified quality. These obligations have yet to be met and the burden of meeting them has yet to be allocated among the various American water users. These issues exist prior to considerations of the use of Colorado River water for energy conversion. Thus, the diversion of Colorado River water from irrigation to electricity generation would further complicate an already complex problem.

# INTRODUCTION

## ENERGY PROBLEMS, RESOURCES AND THE ENVIRONMENT

Coal is being viewed as one part of a solution to this nation's problems of inadequate current supplies of energy from domestic sources and overdependence on imported oil. But the mining, transportation, and burning of coal raise problems of environmental degradation. Moreover, rapid development of massive coal mining operations and huge coal-burning electric power plants in a region also bring problems of major social and economic change, natural resource management, and competition for some of these resources between new and traditional activities. Coal development now underway in the Rocky Mountains is a case in point.

RM coal development, however, is being based to a significant extent on a new twist — mitigation of environmental damage. As one major step to reduce degradation of air quality, federal standards established in 1971 include regulation of sulfur dioxide emissions from fossil fuel combustion. Because one way to meet these emission standards is to burn very low sulfur coal, and because a major part of RM coal reserves qualifies as this type of coal, development of these reserves is accelerating to help slow the deterioration of air quality, given a demand for more electric power from coal-fired facilities.

If RM coal development is to continue to expand for these reasons — adding to the nation's energy supplies with minimal harm to air quality — an obvious problem arises. How can it be done while minimizing damage and maximizing benefits to the RM itself? Public policymakers

and private enterprises alike still have many options concerning how to proceed with coal development in the RM and at what pace. Their options are open because only a fraction of total potential inputs for coal development, such as capital investment in mining, has yet been committed.

## INTEGRATED ASSESSMENT AND THE ESCS PROJECT

What are some of the major options? What are some of the main alternative patterns for RM coal development? Previous reports have addressed these questions and laid important groundwork. (3, 5, 8, 9 12, 17, 22, 34, 37) 1/ However, a more comprehensive analytical system is necessary. An analysis of these options should integrate many diverse impacts into an assessment of alternative systems for coal development and then evaluate the interregional tradeoffs attributable to these alternatives. Thus, ESCS has undertaken a comprehensive assessment in its project "Integrated Assessment: Economic and Social Consequences of Coal and Oil Shale Development," performed in cooperation with EPA.

This research is scheduled to continue through 1981, with the objective of constructing an interregional analytical system based on a large linear programming model. Initially, work focuses on coal and oil shale development in the Western States. Later in the Project, Interior and Eastern States will be brought into the analysis.

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1/ Underscored numbers in parentheses refer to references listed at the end of the report.

This report is the second in a series of regional profile reports examining the human and physical resources of each region. The first report covered the Northern Great Plains. The focus of this RM report is factual and descriptive. It depicts the situation in which the RM found itself in the mid-1970's with respect to coal development and lays the groundwork for analysis. As a "situation report" it can stand on its own, but the report is not intended to represent the project's analysis of coal development alternatives and interregional tradeoffs. That analysis is reserved for future reports containing results of the analysis.

Two other, closely related reports will also be forthcoming as part of this project. One will deal with likely agricultural impacts of possible oil shale development in the "shale country" of Colorado, Utah, and Wyoming. Since these areas of shale deposits are also very close to major coal reserves and to existing coal mining, simultaneous coal and oil shale development, should it occur, could have strong cumulative impacts which would have to be studied jointly.

Another scheduled report, on water and energy development in the West, expands on the water resources analysis in this Rocky Mountain report. The water problem will be treated in the light of potential development of both coal and oil shale.

## METHODOLOGY: COAL PRODUCTION AREAS

Despite the descriptive nature of this report, a key analytical concept is introduced - that of Coal Production Areas (CPA). This is basically

a method of classifying data along subregional, geographical lines to facilitate later assessment of impacts of alternative development patterns upon relatively small areas.

In addition to small-area data, regional aggregate information is also needed. Defining a basic geographic unit for this report (the CPA) permits the subsequent economic model to aggregate and, later disaggregate back down to this smallest geographic unit. In other words, the CPA is the basic geographic "building block" for the analytical system.

After considerable study of data availability, the research team decided that the county, or groups of similar counties, should be used to define the boundary lines of CPA's. At times, site-specific information may be used, but site-by-site data are not always available, uniform, or appropriate to the issue at hand. As a geographic unit for organizing and aggregating basic data, the county is the best compromise between specificity and generality.

However, when a topic or issue warrants, data will be assembled by area unrelated to county lines, such as river basins, or electricity demand regions. It is acknowledged that effects of coal development, such as electric transmission lines or commercial development, often extend well beyond counties of coal production. The use of the CPA concept will not inhibit analysis of such wider geographical effects.

Counties are grouped into CPA's if they contain coal in commercial or potentially commercial quantities. Similarities in type of coal

reserves and physical properties of the coal are the basis for grouping certain counties into one CPA. Some CPA's may consist of only one county, but most contain more than one. Counties where there is currently no known significant amount of coal will not be included in CPA's. The CPA's for the RM are shown in Figure 3.

# Rocky Mountain Coal Production Areas

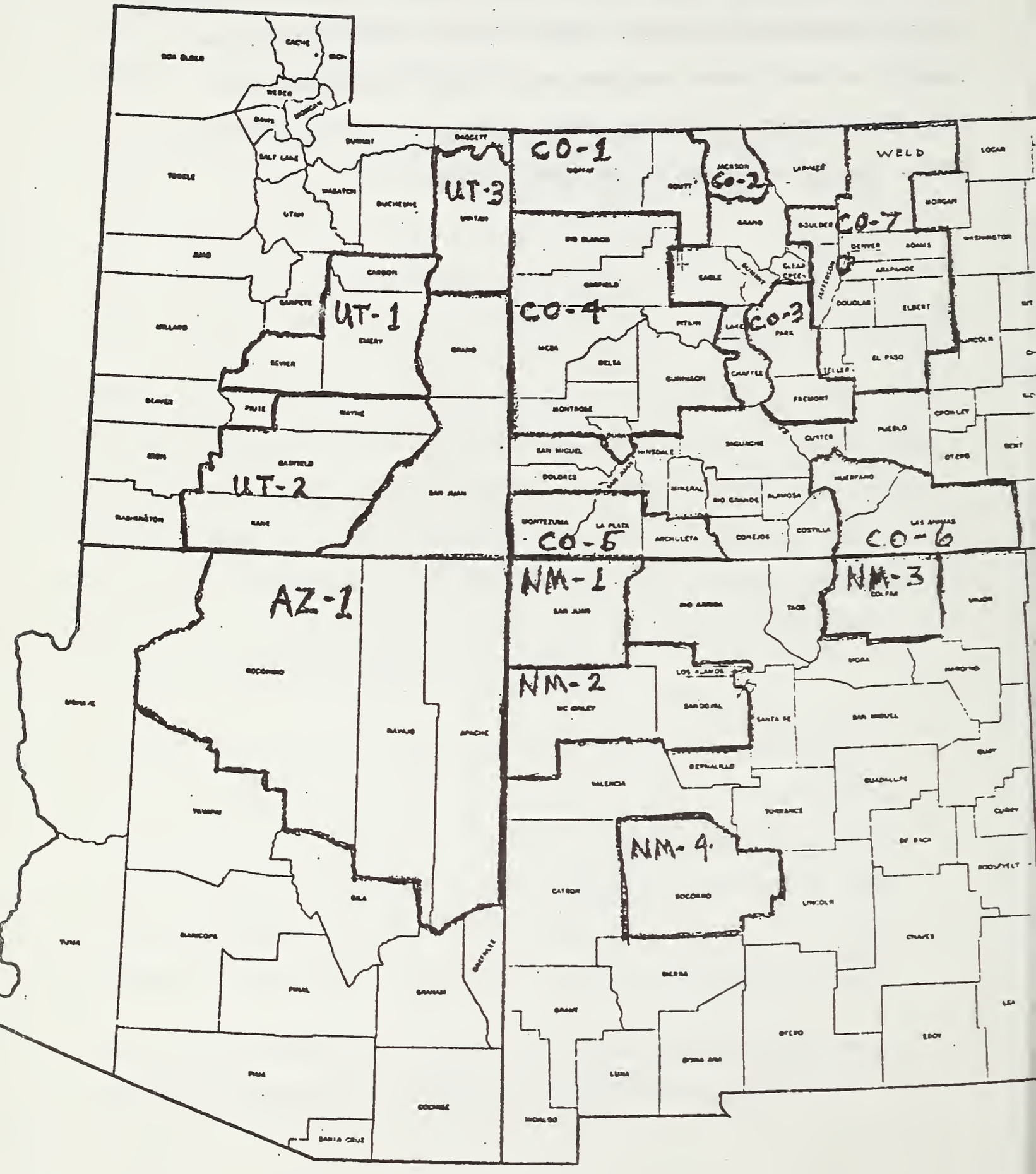


Figure 3

# PEOPLE

by

Paul R. Myers

The people of the RM coal region have diverse socio-economic characteristics. The region's population includes the high income, young and well-educated people who live in suburban communities of the Denver and the Colorado Springs areas, the older populations with higher incomes of the more agriculturally oriented areas of Utah and Colorado, and the high concentrations of relatively low income American Indians and Spanish Americans residing in the sparsely settled areas of Northern New Mexico, Arizona, and Eastern Utah which are currently undergoing intensive energy development.

## POPULATION, MIGRATION, AND EMPLOYMENT

Partly in response to increased coal production, migration rates have been reversed in CPA's such as AZ-1 and NM-1. Migration reversed in both areas, from outmigration in the 1960's to inmigration in the early 1970's. As coal development activities continue, the socioeconomic structure will be greatly altered. This section gives a brief summary of this structure in 1970 and some recent changes which stem from coal mining activity in the areas since 1970.

In 1975, 1.93 million people lived in the Rocky Mountain Coal Region with 67 percent of this total residing in CPA CO-7, which includes Colorado

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Springs and the suburban areas around Denver, but excludes Denver itself. 1/ Since 1940, the region's population has almost tripled—far exceeding the increase for the United States as a whole. (Table 1) Much of this increase during the last 35 years can be attributed to growth in CPA CO-7. At the other extreme, 5 of the 15 CPA's had smaller populations in 1975 than in 1940. (28, 29)

Since 1970, the region's population has increased 23.1 percent—over five times the U.S. increase. Net inmigration during 1970-75 totaled 15.9 percent or over 250,000 people. (29) Two principal forces contributing to the recent population growth rate are: (a) the growth and suburbanization of the metro areas of Denver and Colorado Springs, and (b) the expansion of employment in mining and closely related contract construction in the more sparsely settled areas. (Figures 4 and 5)

Seventy percent of the 1970-75 population increase occurred in CO-7 while CPA's AZ-1, NM-1, NM-2, and UT-3 had percentage increases exceeding 20 percent. For instance, the area with the largest percentage population gain in this period was AZ-1, where population increased by over 36 thousand people and coal production increased from 132 thousand tons to 6.4 million tons. Mining employment increased from 1,510 to 4,178. (30) Prior to 1970, the area had outmigration rates of 13.4 percent in the 1950's and 21.6 percent in the 1960's.

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1/ However, CO-7 is not a likely area for early and extensive coal development. See the following section, "COAL," for a discussion of deep mineable subbituminous reserves, which is the type contained in CO-7.

Table 1--Total population and population changes for metro and nonmetro counties and Rocky Mountain Coal region, 1940-75

| Areas | Total population | | | | | Components of population change | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 1950-60 | | | 1960-70 | | | 1970-75 | | |
| | 1940 | 1950 | 1960 | 1970 | 1975 | Total change | Natural change | Net migration | Total change | Natural change | Net migration | Total change | Natural change | Net migration |
| | Thousands | | | | | Percent | | | | | | | | |
| United States | 132,165.6 | 151,698.8 | 179,323.1 | 203,212.8 | 213,053.9 | 18.2 | 16.7 | 1.5 | 13.3 | 11.6 | 1.7 | 4.8 | 3.6 | 1.2 |
| Metropolitan | 80,386.1 | 100,081.3 | 126,455.4 | 147,996.3 | 154,138.3 | 26.4 | 17.4 | 8.9 | 17.0 | 12.3 | 4.7 | 4.2 | 3.8 | 0.4 |
| Nonmetropolitan | 51,779.5 | 51,617.5 | 52,867.7 | 55,216.5 | 58,915.6 | 2.4 | 15.4 | -13.0 | 4.4 | 10.1 | -5.6 | 6.7 | 3.3 | 3.4 |
| | Number | | | | | | | | | | | | | |
| Rocky Mountain Coal Region, total | 664,685 | 769,631 | 1,162,763 | 1,575,514 | 1,939,900 | 51.1 | 26.9 | 24.2 | 35.5 | 19.2 | 16.3 | 23.1 | 7.2 | 15.9 |
| Arizona 1 | 68,174 | 81,123 | 110,289 | 128,339 | 164,400 | 36.0 | 49.3 | -13.4 | 16.4 | 38.0 | -21.6 | 28.1 | 13.1 | 15.0 |
| Colorado 1 | 15,611 | 14,886 | 12,961 | 12,924 | 18,100 | -12.9 | 14.2 | -27.2 | 1.2 | 10.4 | -9.2 | 40.0 | 6.0 | 34.0 |
| Colorado 2 | 1,798 | 1,976 | 1,758 | 1,809 | 1,800 | -11.0 | 21.4 | -32.4 | 3.0 | 12.6 | -9.6 | 0.5 | 11.6 | -11.1 |
| Colorado 3 | 23,014 | 20,236 | 22,018 | 24,048 | 29,600 | 8.8 | 5.0 | 3.8 | 9.6 | 1.0 | 8.5 | 23.1 | 0.2 | 22.9 |
| Colorado 4 | 89,299 | 97,368 | 111,229 | 123,123 | 142,100 | 14.2 | 15.2 | -0.9 | 10.6 | 9.0 | 1.6 | 15.4 | 3.0 | 12.4 |
| Colorado 5 | 29,763 | 27,901 | 35,878 | 34,884 | 41,400 | 28.6 | 23.2 | 5.4 | -2.8 | 12.1 | -14.9 | 18.7 | 4.6 | 14.0 |
| Colorado 6 | 48,457 | 36,451 | 27,850 | 22,425 | 22,100 | -23.6 | 11.3 | -34.9 | -19.8 | 4.3 | -24.1 | -1.4 | -0.6 | -0.9 |
| Colorado 7 | 246,026 | 342,846 | 655,290 | 1,042,025 | 1,297,000 | 91.1 | 27.7 | 63.5 | 59.0 | 18.8 | 40.2 | 24.5 | 7.1 | 17.4 |
| New Mexico 1 | 17,115 | 18,292 | 53,306 | 52,517 | 65,300 | 191.4 | 63.2 | 128.2 | -1.5 | 24.9 | -26.4 | 24.3 | 9.6 | 14.7 |
| New Mexico 2 | 37,539 | 39,889 | 51,410 | 60,700 | 73,800 | 28.9 | 34.7 | -5.8 | 18.1 | 33.1 | -15.0 | 21.6 | 11.7 | 9.9 |
| New Mexico 3 | 18,718 | 16,761 | 13,806 | 12,170 | 12,900 | -17.6 | 14.9 | -32.5 | -11.8 | 11.6 | -23.4 | 6.0 | 3.5 | 2.5 |
| New Mexico 4 | 11,422 | 9,670 | 10,168 | 9,763 | 9,800 | 5.1 | 23.1 | -18.0 | -4.0 | 21.9 | -25.9 | 0.4 | 7.6 | -7.2 |
| Utah 1 | 37,643 | 43,277 | 37,246 | 30,887 | 36,100 | -13.9 | 19.4 | -33.4 | -17.1 | 8.3 | -25.4 | 16.9 | 5.6 | 11.3 |
| Utah 2 | 10,208 | 8,655 | 7,972 | 7,216 | 8,200 | -7.9 | 20.6 | -28.4 | -11.4 | 12.5 | -23.9 | 13.6 | 2.5 | 11.1 |
| Utah 3 | 9,898 | 10,300 | 11,582 | 12,684 | 17,300 | 12.4 | 26.0 | -13.6 | 9.5 | 20.2 | -10.7 | 36.4 | 12.0 | 24.4 |

Source: Census of population, 1940, 1950, 1960, 1970. The 1975 population estimates taken from Current Population Reports, Series P-26. (28, 29)

ANNUAL POPULATION GROWTH RATES BY SIZE OF TOWN
FOR ROCKY MOUNTAIN COAL REGION, 1940-70, AND 1970-75.

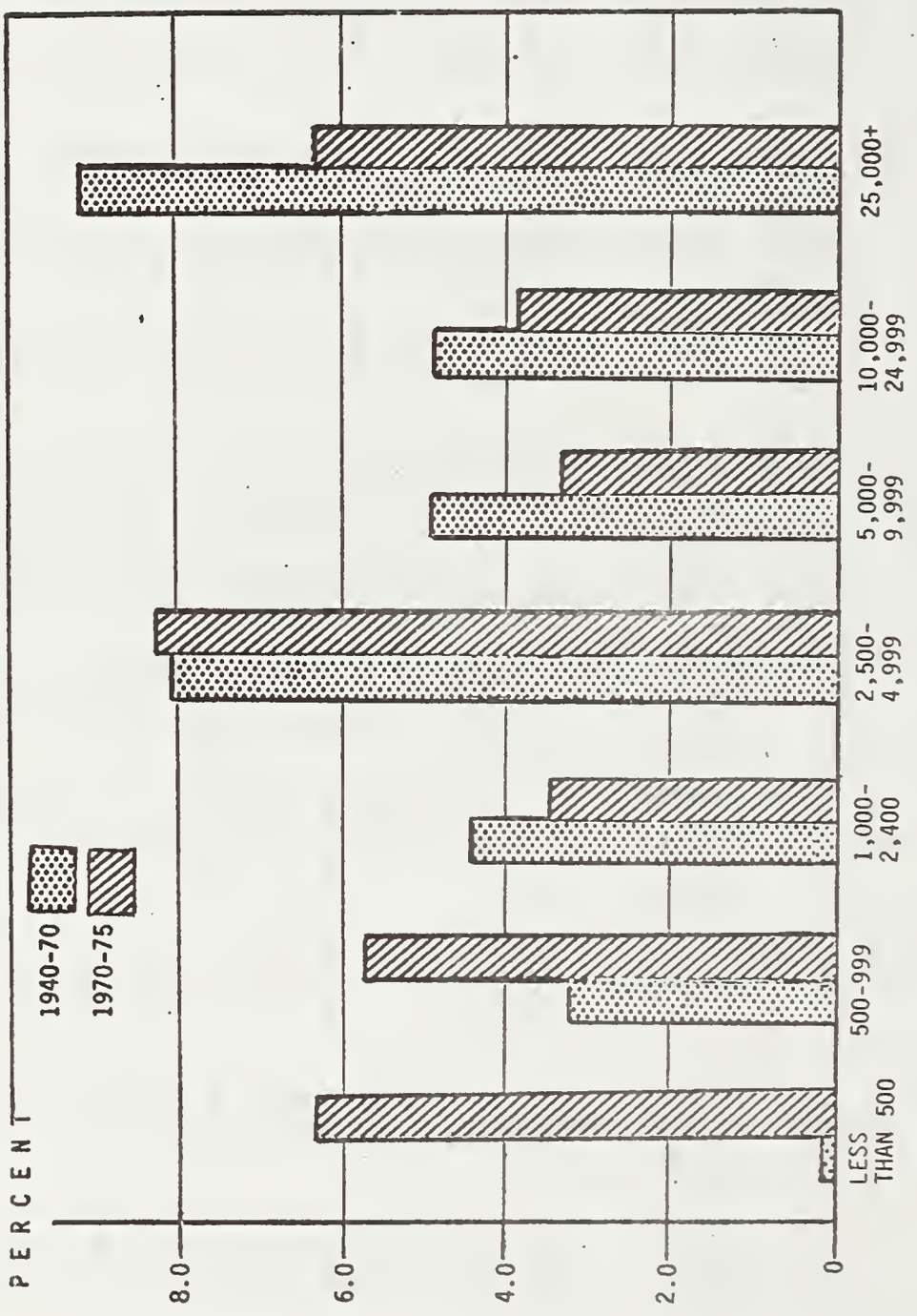


FIGURE 4

CHANGES IN EMPLOYMENT BY SECTOR FOR THE ROCKY MOUNTAIN COAL REGION AND THE UNITED STATES, 1970-74

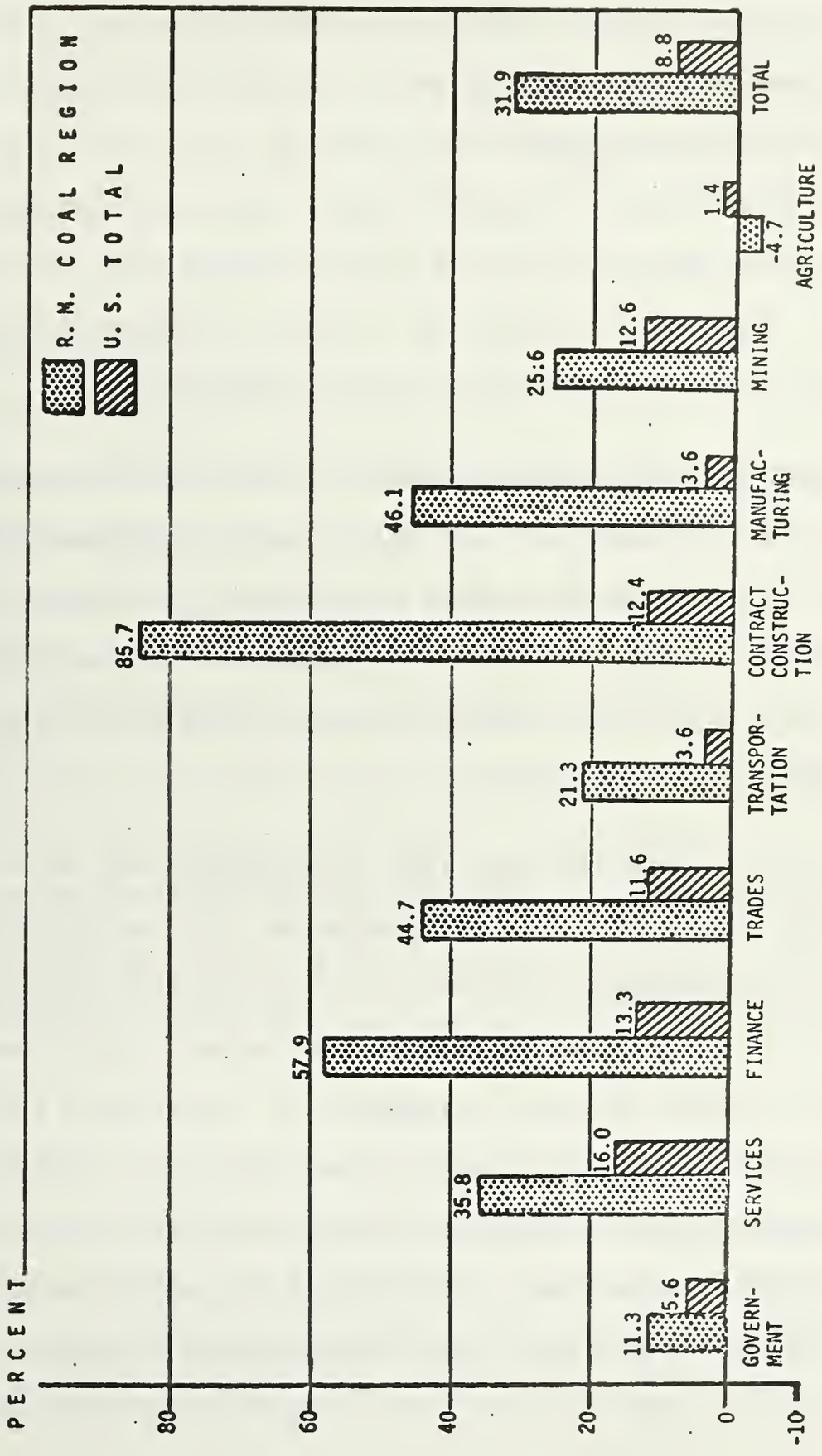


FIGURE 5

The recent rapid population increase in NM-1 is partly an effect of rising coal production. After a boom period of oil exploration in the 1950's and a subsequent decline in the 1960's, the NM-1 area is again experiencing population growth and inmigration. NM-1 led the RM coal region in coal production in 1974 with 7.9 million tons. Coal mining employment increased sharply during the 1970 to 1974 period by 109.4 percent, from 235 to 492 workers. There was a corresponding increase in contract construction employment which was associated with coal mining activity.

Areas other than AZ-1 and NM-1 which in the early 1970's experienced substantial coal-related activity and subsequent employment and population increases were: CO-2, NM-2, NM-3, UT-1 and UT-3. Areas with very little coal mining activity, which were still significantly dependent upon agriculture as a prime economic base, such as CO-2 and NM-4, showed stable population in the early 1970's.

Between 1970 and 1974 the total level of employment for the RM coal region increased 31.9 percent, while the total employment for the United States increased 8.8 percent. This increase in employment amounted to an average annual growth of 6.4 percent, and probably induced the large increases in rates of inmigration. The greatest increase in employment occurred in the contract construction sector, primarily heavy contract construction, indicating a buildup for greater energy development in the future. The contract construction sector added 22,730 new workers during the 1970 to 1974 time span. Mining employment increased 25.6 percent

or nearly twice the percentage increase for U.S. mining employment. The importance of the primary employment increase in mining for the region is its value as a stimulus to related increases in the finance and transportation sectors. Even though the manufacturing employment grew by 25,431 workers, almost all of these workers (89.9 percent) were located in the CO-7 CPA, where energy development has had little, if any impact.

SELECTED CHARACTERISTICS

In 1970, almost one-fifth of the RM coal region's population belonged to one of three minority groups: American Indians, Spanish Americans, or Blacks. These three groups comprised 7.5, 9.0 and 1.3 percent of the total population, respectively. American Indians of the region were concentrated in the Navajo and Hopi reservations (AZ-1), the Ute Mountain, Navajo and Zuni reservations (NM-1 and NM-2) and the much smaller Uintah and Ouray reservations (UT-3). The majority of Spanish Americans in the region lived in CO-7 in 1970 while areas such as CO-6, NM-2, NM-3 and NM-4 had very high concentrations of Spanish Americans, ranging from one-fifth to over one-half of the total population in these areas. A majority of the Blacks in the region lived in Colorado Springs (CO-7).

Overall, the region's population was younger, more mobile, slightly better educated, and had higher fertility rates than the U.S. population. Incomes and poverty levels for the region as a whole were similar to those of the U.S. However, all the characteristics varied greatly across areas of the region, with areas containing larger concentrations of minorities

typically having larger dependent age groups, substantially higher fertility rates, and despite their relatively young populations, lower educational attainment than the U.S. average. Also areas of high concentration of minorities had substantially lower incomes and higher poverty rates than the U.S. Table 2 illustrates the contrast in selected demographic characteristics between the suburban areas (CO-7), and NM-2, which contained a large concentration of both American Indians and Spanish Americans.

TABLE 2 .--Demographic Characteristics

| Characteristics | United States | Rocky Mountain coal region | | |
|---|---|---|---|---|
| | | TOTALS | CO-7 | NM-2 |
| Percent American Indian | 0.39 | 7.5 | 0.2 | 54.9 |
| Percent Spanish Speaking | 4.7 | 9.0 | 7.0 | 20.4 |
| Median age, 1970 (yrs.) | 28.1 | 24.3 | 24.4 | 19.5 |
| Median school years, persons 25 years old and over, 1970 | 12.1 | 12.4 | 12.6 | 10.2 |
| Fertility (children born per 1,000 women 35-44 years old) | 2956.0 | 3182.4 | 2934.8 | 4322.5 |
| Pct. of population 14 years and over in labor force: | | | | |
| Males | 72.9 | 74.5 | 79.7 | 58.1 |
| Females | 39.6 | 38.8 | 41.5 | 31.0 |
| Median earnings (Dols.): | | | | |
| Males | 7,515 | 7,603 | 8,226 | 5,286 |
| Females | 3,413 | 3,018 | 3,300 | 2,845 |
| Median family income (dols.) | 9,590 | 9,601 | 10,685 | 6,383 |
| Pct. of persons in poverty | 13.7 | 14.7 | 8.7 | 41.4 |
| Substandard housing | 6.5 | 7.5 | 2.5 | 36.7 |

Sources: (27, 28, 29, 30)

The American Indian population in the areas of New Mexico and Arizona where impacts of coal development are already being felt have socio-economic characteristics that differ greatly from the region as a whole. For instance, in 1970, 58 percent of the Indian population in AZ-1 was less than 20 years old, mirroring the extremely high fertility rate of 5.7 children born for each woman 35-44 years of age—almost twice the U.S. average. The median school years completed for adults of this population was only 6.3 years, roughly half that of the U.S. as a whole. And among 16-17 year olds, one-fifth were not enrolled in school. Further, only 40 percent of the males 14 years and older were in the labor force; median family income was $4,337 and the incidence of poverty was 63 percent. This poverty level was over four and one-half times the national average.

These characteristics for American Indians in AZ-1 are similar to those for Indians in other areas of the region. While these figures reflect the low level of living of the Indian population currently impacted by coal development, they also suggest possible difficulty in adapting to the development, and explain the increasing concern on the part of the American Indians about sharing in the potential benefits from the development in terms of jobs and income and ownership and rights to the coal itself.

GROWTH IN TOWNS

In general, most towns in the RM coal region gained in population between 1940 and 1970. However, the firmest growth occurred

in larger towns. This was similar to the population changes for the nation as a whole. While larger towns grew during the 30 year period, smaller towns, especially those with 1940 populations of less than 500 people, experienced very little growth. (Figure 4) During the 1970 to 1975 period, strong population growth rates were evident for all size towns, with the small to middle size towns having the largest percentage increases.

Much of the population growth during the earlier period occurred in the larger towns of CO-7 due to the suburbanization and development of the recreation industry, such as, Boulder, Greeley, Aurora, and Colorado Springs, as well as Aspen in CO-4. Aurora had a population of 3,437 people in 1940 and by 1970 had grown to 74,974, which is an example of the suburbanization of the Denver, Colorado area. Other examples of suburbanization in the region, for towns in the 500-999 population size range, are Westminister, Fountain and Evans in CO-7. Only one town, Aztec in NM-1, experienced large population growth which coincided with increasing coal production. Aztec had 756 people in 1940, and by 1970 had enlarged its population to 3,354, while the NM-1 CPA steadily increased its coal production.

While most population growth was in the larger towns from 1940 to 1970, the early 1970's brought a surge in coal production accompanied by renewed viability in small towns as shown in Figure 4. Some examples of 1970-75 small town growth coinciding with heightened interest in energy development are: Hayden in CO-1 from 763 to 1,338 people;

Crested Butte in CO-4 from 372 to 868 people; Oak Creek in CO-1 from 492 to 780 people; and Dacona in CO-7 grew from 360 people in 1970 to 1,243 by 1975.

Although these increases are not large in absolute numbers, they represent substantial, relative impacts on small towns in a short span of time. Most of the increased population in the towns of less than 500 people, from 18,262 to 24,065 people in five years, however, was spread out evenly among the many small towns.

# COAL

by

Virgil Whetzel

## RESOURCES AND RESERVES

The Rocky Mountain region contains about 14 percent of those U.S. coal resources at depths shallower than 3,000 feet and about 19 percent of U.S. coal resources, measured as estimated tons in the ground. (4) However, of all U.S. coal reserves, only 5.4 percent are in the RM region. 1/

These comparisons are made without adjustments for differing heat values among coals. To make accurate comparisons of coal reserves among regions, or even comparisons among different coals of the same region, the units of measure should be common. Either a heat unit (BTU) or a tonnage adjusted to a standard BTU basis is satisfactory as a common measuring unit. Nevertheless, the average heat value per ton of RM coal is almost the same as that for all U.S. coal. 2/ (13, 24)

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1/ The terms coal "resources" and coal "reserves", which must be distinguished, are used here as defined by the U.S. Geological Survey and Bureau of Mines. (4, 13) In general, the term "resources" means the total quantity of coal in the ground within a certain depth, and within a specified limit of coal bed thickness. By contrast, the term "reserves", that is, "reserve base," is much more restrictive, denoting only some of the "demonstrated resources" and of these only those legally and economically mineable with present technology and equipment. Even though a deposit is classified as a "reserve" it is not necessarily attractive for near term development. A deposit may be reclassified from "resource" to "reserve" if both economic factors and extraction technology improve.

2/ The heat content of RM coal averages 22.9 million BTU per ton, ranging from a 20.7 million average for Arizona coal to a 23.7 million average for New Mexico coal. A typical eastern bituminous coal contains 26.2 million BTU per ton. An approximate national average is 22.6 million BTU per ton.

When the tonnages of all U.S. coal reserves are adjusted to a "standard BTU coal" basis, the estimate of the proportion of U.S. coal reserves located in the Rocky Mountains increases hardly at all—only from 5.4 to 5.6 percent. 3/ On a standard basis, 3 percent of all U.S. coal reserves is in Colorado, about 1 percent each in both New Mexico and Utah and only 0.1 percent in Arizona. At the 1976 rate of RM coal production — about 37 million tons annually — the region's reserves would last about 640 years. Arizona's reserves would last about 35 years; Colorado's 1580, New Mexico's 450, and Utah's 510. These are merely illustrations of size, not forecasts, since production of coal in the RM region is likely to increase.

## Coal Rank

RM coal reserves are of bituminous and sub-bituminous ranks, plus a very little anthracite. 4/ About two-thirds of these reserves are bituminous. Arizona coal reserves rank as only sub-bituminous, while Utah reserves rank as only bituminous. Colorado and New Mexico have reserves of both bituminous and sub-bituminous ranks, with sub-bituminous being predominant in

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3/ A "standard BTU coal" is defined in this report as that coal which yields 22.6 million BTU per ton. Therefore, a quantity of any other coal of a nonstandard BTU value per ton, yielding a certain total heat value for that tonnage can be adjusted to a standard BTU coal tonnage yielding an equivalent total heat value. The adjusted quantity is called "standard equivalent".

4/ Rank is assigned to a coal according to its percentage of fixed carbon, the main determinant of its heat value. In general, the higher the percentage of fixed carbon, the higher the rank. However, the rank is calculated only after first excluding a coal's mineral and ash content from the calculation. Minerals and ash content are used to calculate a coal grade (quality) within a rank; in general, the greater the mineral and ash content, the lower the quality.

New Mexico and bituminous predominant in Colorado. In Colorado only the bituminous coal deposits are surface mineable, but coal in both bituminous and sub-bituminous deposits is surface mineable in New Mexico.

There is no simple correlation between bituminous and deep mineable coal on the one hand, and between sub-bituminous and strippable coal on the other hand. (Table 3) Almost all existing deep mining is of bituminous coal, although bituminous is strip mined as well. Almost all current production of sub-bituminous coal is from strip mining.

Strippable and Deep-mineable Reserves

However, a substantial quantity of deep mineable sub-bituminous coal is classified as "reserves" (almost 5.4 billion tons — Table 3). The "reserves" classification suggests that the changes in technology and economic relationships necessary to make it profitable to extract the deeply-buried, relatively low-energy sub-bituminous coal are not impossible to imagine. The interregional analytical system referred to in the Introduction to this report can address the questions of whether, why, and when these deep mineable sub-bituminous reserves might be developed.

Unadjusted for heat value differences, all Rocky Mountain coal reserves total about 23.7 billion tons (1974) of which 19.9 billion were classified by the U.S. Bureau of Mines as accessible only by underground mining, and 3.7 billion by surface mining alone. All but a negligible amount of these coal reserves are located within the 15 Rocky Mountain Coal Production Areas (CPA's) defined in this report. (Table 3)

Table 3.--Coal reserves of the Rocky Mountain Region, 1974

| State and CPA | Reserves | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Bituminous | | | Subbituminous | | | Total | | |
| | Deep mineable | Strippable | Total | Deep mineable | Strippable | Total | Deep mineable | Strippable | Total |
| | Million tons | | | | | | | | |
| **Arizona** | | | | | | | | | |
| AZ-1 | 0 | 0 | 0 | 0 | 350.0 | 350.0 | 0 | 350.0 | 350.00 |
| **Colorado** | | | | | | | | | |
| CO-1 | 4,733.5 | 683.0 | 5,416.5 | 1,251.0 | 0 | 1,251.0 | 5,984.5 | 683.0 | 6,667.5 |
| CO-2 | 0 | 127.0 | 127.0 | 823.0 | 0 | 823.5 | 823.5 | 127.0 | 950.5 |
| CO-3 | 180.3 | 0 | 180.3 | 0 | 0 | 0 | 180.3 | 0 | 180.3 |
| CO-4 | 2,743.6 | 60.0 | 2,803.6 | 1,296.9 | 0 | 1,296.9 | 4,040.5 | 60.0 | 4,100.5 |
| CO-5 | 433.3 | 0 | 433.3 | 0 | 0 | 0 | 433.3 | 0 | 433.5 |
| CO-6 | 1,110.3 | 0 | 1,110.3 | 0 | 0 | 0 | 1,110.3 | 0 | 1,110.3 |
| CO-7 | 0 | 0 | 0 | 1,367.9 | 0 | 1,367.9 | 1,357.9 | | 1,367.9 |
| Total CPA's 1/ | 9,201.0 | 870.0 | 10.071.0 | 4,739.3 | 0 | 4,739.3 | 13,940.3 | 870.0 | 14,810.3 |
| Not in CPA's | 0 | 0 | 0 | 6.0 | 0 | 6.0 | 33.6 | 0 | 33.6 |
| Total CO | 9,226.2 | 870.0 | 10,096.2 | 4,745.3 | 0 | 4,745.3 | 13,999.2 2/ | 870.0 | 14,869.2 2/ |
| **New Mexico** | | | | | | | | | |
| NM-1 | 94.7 | 0 | 94.7 | 442.2 | 2,008.3 | 2,450.5 | 536.9 | 2,008.3 | 2,545.2 |
| NM-2 | 3.5 | 250.0 | 253.5 | 161.7 | 0 | 161.7 | 165.2 | 250.0 | 415.2 |
| NM-3 | 1,381.0 | 0 | 1,381.0 | 0 | 0 | 0 | 1,381.0 | 0 | 1,381.0 |
| NM-4 | 27.5 | 0 | 27.5 | 0 | 0 | 0 | 27.5 | 0 | 27.5 |
| Total CPA's 1/ | 1,506.7 | 250.0 | 1,756.7 | 603.9 | 2,008.3 | 2,612.2 | 2,110.6 | 2,258.3 | 4,368.9 |
| Not in CPA's | 20.5 | 0 | 20.5 | 3.1 | 0 | 3.1 | 25.9 3/ | 0 | 25.9 3/ |
| Total NM | 1,527.2 | 250.0 | 1,777.2 | 607.0 | 2,008.3 | 2,615.3 | 2,136.5 | 2,259.3 | 4,394.8 |
| **Utah** | | | | | | | | | |
| UT-1 | 986.4 | 20.0 | 1,006.4 | 0 | 0 | 0 | 986.4 | 20.0 | 1,006.4 |
| UT-2 | 2,748.5 | 242.0 | 2,990.5 | 0 | 0 | 0 | 2,748.5 | 242.0 | 2,990.5 |
| UT-3 | 40.3 | 0 | 40.3 | 0 | 0 | 0 | 40.3 | 0 | 40.3 |
| Total CPA's 1/ | 3,775.2 | 262.0 | 4,037.2 | 0 | 0 | 0 | 3,775.2 | 262.0 | 4,037.2 |
| Not in CPA's | 5.3 | 0 | 5.3 | 0 | 0 | 0 | 5.3 | 0 | 5.3 |
| Total UT | 3,780.5 | 262.0 | 4,042.5 | 0 | 0 | 0 | 3,780.5 | 262.0 | 4,042.5 |
| Total RM CPA's 1/ | 14,482.9 | 1,382.0 | 15,864.9 | 5,343.2 | 2,358.3 | 7,701.5 | 19,826.1 | 3,740.3 | 23,566.4 |
| Total RM not in CPA: | 25.7 | 0 | 25.7 | 9.1 | 0 | 9.1 | 64.4 2/ 3/ | 0 | 64.4 2/ 3/ |
| Total RM | 14,533.9 | 1,382.0 | 15,915.9 | 5,352.3 | 2,358.3 | 7,710.6 | 19,916.2 | 3,740.3 | 23,656.5 |

1/ Data may not add to totals because of rounding.
2/ Includes 27.7 million tons of anthracite.
3/ Includes 2.3 million tons of anthracite.
Source: The Reserve Base of U.S. Coals by Sulfur Content (in two parts). 2. The Western States. U.S. Bureau of Mines Information Circular 8693. (13)

Almost all of the surface mineable (strippable) reserves of 3.7 billion tons are located in 9 of the Rocky Mountain Coal Production Areas. (Table 3). Of this amount, about 62 percent is located in the CPA's of New Mexico, 23 percent in those of Colorado, 9 percent in Arizona, and 6 percent in Utah. Since the heat content of strippable Rocky Mountain coal approximates that of standard coal (22.6 million BTU's per ton) these percentages are about the same on both an actual and standard equivalent basis.

Deep mineable bituminous reserves are concentrated in Colorado, 9.2 billion tons, and Utah 3.8 billion. New Mexico has 1.5 billion tons. Colorado also has most of the deep mineable sub-bituminous reserves, 4.7 billion tons; New Mexico has 0.6 billion tons.

Sulfur Content

Sulfur content is a key factor in determining coal quality, especially in light of federal air quality standards. If sulfur content is low enough, a coal, when burned, will meet 1971-1977 Clean Air Act sulfur dioxide

emission standards without using scrubbers to desulfurize flue gases (but not the standards in effect for 1978 and beyond.) (See footnote below.) 5/

Coal containing 0.6 pound or less of sulfur per million BTU will meet these emissions standards and is therefore defined in this report as "SO2 compliance coal". 6/

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5/ Sulfur in coal burned by electric power plants contributes to equipment corrosion and the formation of boiler deposits. Sulfur oxides as combustion products emitted to the atmosphere can be injurious to many forms of life, including humans and crops and forests. In recognition of these deleterious effects, sulfur dioxide in the atmosphere and sulfur dioxide from certain emissions are limited by the Clean Air Act (CAA) through its provisions for 1) air quality and standards to be achieved by "State implementation plans" (SIP), and 2) new source performance standards (NSPS) for new electric generating plants and other new facilities constructed since 1971. The NSPS in effect from 1971 through 1977 required that no more than 1.2 pounds of sulfur dioxide be emitted per million BTU of fuel burned. Sulfur dioxide is formed at that approximate rate during normal combustion of coal containing 0.6 pound of sulfur per million BTU. Therefore, at this rate of sulfur dioxide formation no more than 0.6 pound of sulfur per million BTU can be present (in order to comply with NSPS) in a fuel intended for combustion without the use of flue gas desulfurization equipment (stack gas scrubbers). It follows that for a standard BTU coal containing 22.6 million BTU per ton, the defacto upper limit is 14 pounds of sulfur per ton or 0.7 percent sulfur, if the coal is to yield sulfur dioxide emissions (withoutscrubbers) no greater than the legal limit for 1971-77 "new sources". NSPS mandated by the 1977 Clean Air Act Amendments prescribe "best available control technology", generally interpreted as stack gas scrubbers. Nevertheless, sulfur content is still an important consideration since scrubbers are not required for 1971-77 new sources, and since coal sulfur content affects scrubber operations. In general, the lower the coal sulfur content, the easier the scrubber operation and the better the potential for removing a high percentage of a coal's sulfur content.

6/ However, the concept of "compliance coal" is already established. The term is used in the coal trade, and refers to likely compliance with SO2 NSPS. Also, the concept of coal which complies with current SO2 emission standards imbues a recent report on coal sulfur content prepared by the U.S. Bureau of Mines. (6)

It is important to know how much of the RM's coal reserves can be classified as SO2 compliance coal. Burning this low sulfur coal without stack gas scrubbers is a major alternative to installing stack gas scrubbers for those electric plants governed by the 1971-77 NSPS.

Researchers at Argonne National Laboratory have estimated the amount of NSPS coal available, on a county basis, for the United States using the following formula:

(pounds SO2 emmitted/ton of coal fired) =38S

where 38 is a constant and S is the percentage sulfur in the coal (for coal containing 2% sulfur, S = 2). If the heating value of the coal is $H$ (in $10^3$ BTU/lb), then a generating unit meeting the NSPS must have

(lb SO2 emitted/$10^6$ BTU) = 38S(lb SO2 emitted/ton of coal fired)
X (1/2000) (ton/lb)
X 1/H (lb of coal/103 BTU)
= 1.2(lb SO2/106 BTU) (NSPS limit)
or, (S/H) = .0632 for NSPS

As an example, with 12,000 BTU/lb. (H = 12), the sulfur content must be 0.76% ( = .0632 X 12) or less to meet NSPS. (23)

Roughly 18 billion tons, or 75 percent of the RM's total reserves is estimated to be SO2 compliance coal. Over two-thirds of this compliance coal is located in Colorado. (Table 4)

Reserve Characteristics and Mining Economics

Although many factors affect the economic feasibility of strip mining of coal at any given site, the main factor is the thickness of overburden relative to the thickness of the coal seam, that is, the stripping ratio. The lower the stripping ratio, the better. For the RM strippable coal reserves, overburden averages 90 feet and seam thickness 11 feet, for an average stripping ratio of 8.2:1. Among the CPA's the

Table 4. -- Rocky Mountain coal reserves by sulfur content to heating value ratio

| State and CPA | Coal Reserves 1/ Sulfur Content/Heating Value (% S/10³ BTU/lb.) .021 | .042 | .050 | .063 2/ | .100 | .210 | .246 | .316 |
|---|---|---|---|---|---|---|---|---|
| | Million tons | | | | | | | |
| Arizona | | | | | | | | |
| AZ-1 | 0 | 0 | 0 | 0 | 329 | 350 | 350 | 350 |
| Colorado | | | | | | | | |
| CO-1 | 2,841 | 2,893 | 4,835 | 4,835 | 6,505 | 6,668 | 6,668 | 6,668 |
| CO-2 | 0 | 951 | 951 | 951 | 951 | 951 | 951 | 951 |
| CO-3 | 1 | 96 | 98 | 168 | 180 | 205 | 205 | 205 |
| CO-4 | 223 | 3,430 | 3,430 | 3,870 | 4,071 | 4,128 | 4,128 | 4,128 |
| CO-5 | 0 | 111 | 111 | 111 | 111 | 111 | 111 | 111 |
| CO-6 | 0 | 843 | 843 | 1,109 | 1,109 | 1,109 | 1,109 | 1,109 |
| CO-7 | 7 | 899 | 943 | 981 | 1,334 | 1,369 | 1,369 | 1,369 |
| Total | 3,072 | 9,545 | 11,533 | 12,347 | 14,583 | 14,863 | 14,863 | 14,863 |
| New Mexico | | | | | | | | |
| NM-1 | 0 | 0 | 0 | 2,545 | 2,545 | 2,545 | 2,545 | 2,545 |
| NM-2 | 0 | 364 | 364 | 364 | 364 | 416 | 416 | 416 |
| NM-3 | 0 | 1,381 | 1,381 | 1,381 | 1,381 | 1,381 | 1,381 | 1,381 |
| NM-4 | 0 | 11 | 11 | 27 | 27 | 28 | 28 | 28 |
| Total | 0 | 1,756 | 1,756 | 4,317 | 4,317 | 4,370 | 4,370 | 4,370 |
| Utah | | | | | | | | |
| UT-1 | 0 | 87 | 87 | 854 | 854 | 1,006 | 1,006 | 1,006 |
| UT-2 | 0 | 31 | 31 | 31 | 1,067 | 2,990 | 2,990 | 2,990 |
| UT-3 | 0 | 31 | 31 | 31 | 32 | 40 | 40 | 40 |
| Total | 0 | 149 | 149 | 916 | 1,953 | 4,036 | 4,036 | 4,036 |
| Total RM | 3,072 | 11,450 | 13,438 | 17,637 | 21,182 | 23,619 | 23,619 | 23,619 |
| | Percent 1/ | | | | | | | |
| Arizona | | | | | | | | |
| AZ-1 | 0 | 0 | 0 | 0 | 94.0 | 100.0 | 100.0 | 100.0 |
| Colorado | | | | | | | | |
| CO-1 | 42.6 | 43.4 | 72.5 | 72.5 | 97.6 | 100.0 | 100.0 | 100.0 |
| CO-2 | 0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| CO-3 | .5 | 46.8 | 47.8 | 82.0 | 87.8 | 100.0 | 100.0 | 100.0 |
| CO-4 | 5.4 | 83.1 | 83.1 | 93.8 | 98.6 | 100.0 | 100.0 | 100.0 |
| CO-5 | 0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| CO-6 | 0 | 76.0 | 76.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| CO-7 | .5 | 65.7 | 68.9 | 71.7 | 97.4 | 100.0 | 100.0 | 100.0 |
| Total | 20.7 | 64.2 | 77.6 | 83.1 | 100.0 | 100.0 | 100.0 | 100.0 |

Table 4.—Continued

| State and CPA | Coal Reserves 1/ Sulfur Content/Heating Value (% S/10³ BTU/lb.) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | .021 | .42 | .050 | .063 2/ | .100 | .210 | .246 | .316 |
| | (Percent) 1/ | | | | | | | |
| New Mexico: | | | | | | | | |
| NM-1 | 0 | 0 | 0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| NM-2 | 0 | 87.5 | 87.5 | 87.5 | 87.5 | 100.0 | 100.0 | 100.0 |
| NM-3 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| NM-4 | 0 | 39.3 | 39.3 | 96.4 | 96.4 | 100.0 | 100.0 | 100.0 |
| Total | 0 | 40.2 | 40.2 | 98.8 | 98.8 | 100.0 | 100.0 | 100.0 |
| Utah | | | | | | | | |
| UT-1 | 0 | 8.7 | 8.7 | 84.9 | 84.9 | 100.0 | 100.0 | 100.0 |
| UT-2 | 0 | 1.0 | 1.0 | 1.0 | 35.1 | 100.0 | 100.0 | 100.0 |
| UT-3 | 0 | 77.5 | 77.5 | 77.5 | 80.0 | 100.0 | 100.0 | 100.0 |
| Total | 0 | 3.7 | 3.7 | 22.7 | 48.4 | 100.0 | 100.0 | 100.0 |
| Total RM | 13.0 | 48.5 | 56.9 | 74.7 | 89.7 | 100.0 | 100.0 | 100.0 |

1/ Entries indicate reserves with S/H ratio less than or equal to value hence are cumulative in any row.

2/ Meets federal New Source Performance Standards (NSPS) without flue gas desulfuring action.

Source: Argonne National Laboratory. Coal Supply and Air Quality Limitations on Fossil Fueled Energy Centers. August 1976. (23)

variation ranges from an average of 90 feet of overburden and 8 feet of seam thickness, 11.3:1 ratio, in NM-2, to an average of 120 feet overburden and 24 feet seam thickness, 5.0:1 ratio in CO-2. (13, 36)

Another way to express these relationships is as cubic yards of overburden per ton of coal. By this concept, RM strippable reserves average 9.1 cubic yards of overburden per ton, ranging from 12.8 cubic yards in NM-2 to 5.6 cubic yards in CO-2. (13, 36) Clearly, CO-2 has the highest coal yield in the region relative to the volume or thickness of strippable overburden. On still another basis — tons of coal per acre of surface area above the coal — CO-2 also leads, averaging 31,000 tons of reserves (standard BTU coal) per acre. CPA UT-2 has the next highest quantity of reserves per acre, 19,000 tons (standard) per acre. (13, 36) This compares to the average for the entire RM of 16,000 tons (standard) per acre. (13, 36)

Coal reserves per acre of these magnitudes are relatively large. By comparison, strippable coal reserves in Illinois average about 9,000 tons per acre, about 7,050 tons per acre in Ohio, 6,450 tons per acre in Eastern Kentucky and 10,600 tons per acre in West Virginia (all standard BTU coal basis). (12) The coal seams in these states are much thinner than in the RM. As a result, strippable reserves per acre in CO-2, for example, are five times the reserves per acre in Eastern Kentucky. When mining commences, the amount of reserves per acre is a major influence on production of coal per acre, and on mining costs per ton.

## PRODUCTION AND UTILIZATION

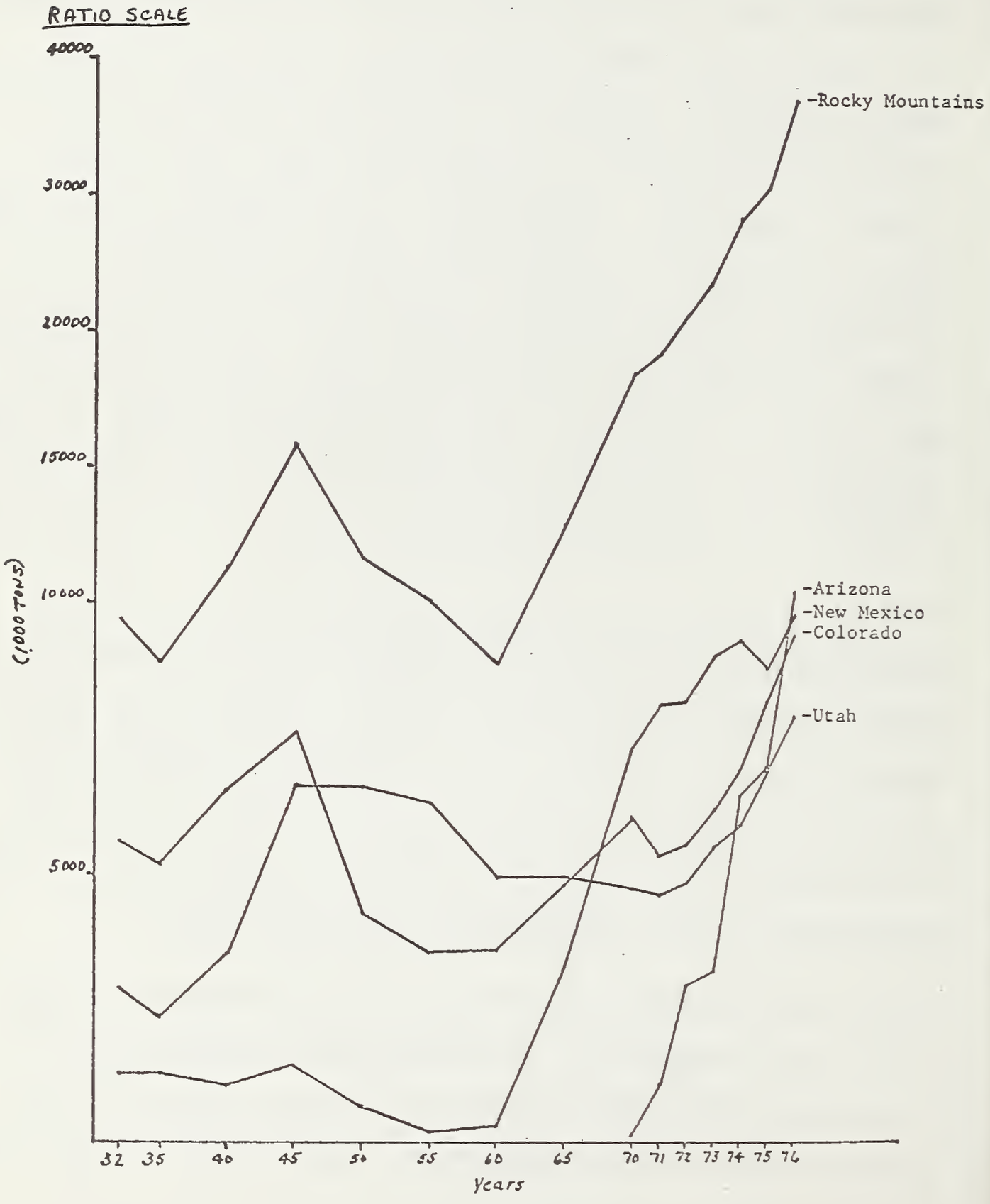
### Historical Slump, Recent Growth

Historically, the Rocky Mountain Region has not been considered a major coal producing area. However, in recent years as demand has risen, especially demand for compliance coal, so has mining activity. In 1932, the RM region produced about 9.7 million tons of coal, only 3.1 percent of total U.S. production. Subsequently, with the exception of the mid-1940's, RM coal production declined through 1960, when only 2.1 percent of total U.S. production was from the Rocky Mountains. By 1965, however, production of coal in the RM had begun to trend upward, and in that year 13 million tons, 2.5 percent of total U.S. production came from that region. By 1976, production from the Rocky Mountains reached 37 million tons, 5.6 percent of the U.S. total. (Figure 6) (31, 35)

Historical trend data for individual states are also shown in Figure 6. With the exception of Arizona, mining activity in all the RM states has increased considerably in the period 1960-1976. Arizona coal production began increasing only in 1970. As coal production has increased, the proportion being extracted by surface mining has also risen. In 1940, less than one percent of the coal produced in the Rocky Mountains was by surface mining methods. In 1976, 68 percent was mined by this method.

In 1975, there were 60 mines operating in the Rocky Mountains. Of these mines, 21 were surface mines. With the exception of Utah, which had 20 underground mines, producing about 7 million tons, coal was extracted by surface mining in all of the RM states. Of the 21 surface mines in the

Figure 6. Coal Production in the Rocky Mountains, 1932-1976




Sources (29, 33)

Rocky Mountains, 9 produced over 500,000 tons each in 1975. These 9 mines accounted for approximately 66 percent of the RM coal production.

In 1975, New Mexico had the largest production, producing about 8.8 million tons in its 5 surface mines. Colorado was a close contender, producing 8.2 million tons from 33 mines. Arizona and Utah, having 2 and 20 mines respectively, produced about 7 million tons each.

## Origin and Destination

Demand for RM coal outside that region has led to increased coal shipment from the region. However, by 1976 over two-thirds of the coal produced within the region was utilized there. In 1975, shipments were made to 18 non-RM states. (Table 5)

The geographic distribution pattern is different for coal from each of the 4 main producing states of the RM. In 1975, Colorado consumed 9 million tons (63 percent) of its own coal production, shipping 16 percent for use elsewhere in the RM region (Utah), while shipping 1.9 million tons (21 percent) outside the RM. Utah used 3.1 million tons (46 percent) of its own coal production, shipping less than 0.2 million tons to other RM states and sending 3.5 million tons (52 percent) outside the RM. Arizona and New Mexico, combined, consumed 11.2 million tons (74 percent) of their own coal output, shipping none elsewhere in the RM, but sending 3.9 million tons (26 percent) outside the RM, all to California and Nevada. (Figure 7)

## Mining and Transportation Costs

The cost of mining coal in the RM is one important determinant of its competitive position in demand areas with respect to alternative fuels and

coals of most other regions. Of course, allowances for transportation costs are necessary to determine, for example, how far east RM coal can be competitive with Interior and Appalachian coal. In general, the cost of mining a ton of coal in the RM is less than in the Interior or East, which contributes to the economic strength of the RM coal.

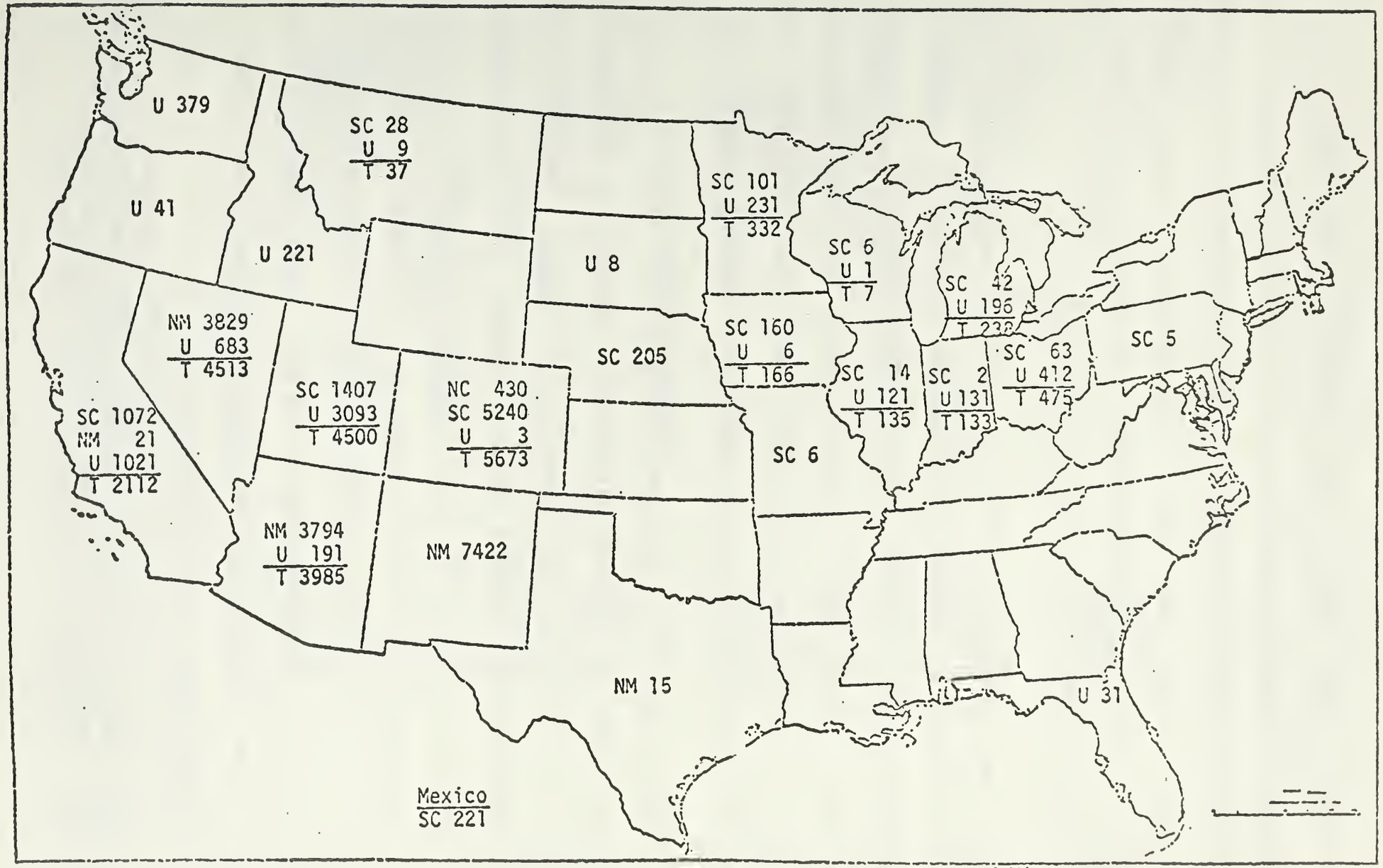
Table 5.--Out-of-Region coal shipments from the Rocky Mountain Region, 1970-1976.

| Year | Total distribution | Out-of-Region shipments | Percent of total |
|---|---|---|---|
| | 1,000 tons | 1,000 tons | Percent |
| 1970 | 18,015 | 8,677 | 22 |
| 1971 | 19,207 | 3,291 | 17 |
| 1972 | 21,996 | 2,949 | 13 |
| 1973 | 23,962 | 3,353 | 14 |
| 1974 | 28,520 | 6,563 | 23 |
| 1975 | 30,878 | 9,298 | 30 |
| 1976 | 36,899 | 11,425 | 31 |

Source: U.S. Department of the Interior, Bureau of Mines, Mineral Industry Surveys, Bituminous Coal and Lignite Distribution. Calendar year 1976 (and earlier years). (33) For conceptual reasons, total distribution amounts differ slightly from production amounts reported in other Bureau of Mines time series.

Several approaches are used to estimate average cost of mining a ton of coal in the RM. Cost budgeting for "model" mines with different configurations typical of the RM has been employed by the U.S. Bureau of Mines. Assumptions are made about the kinds and sizes of mining equipment suited for the assumed layouts, overburden, and mining plans. Then, costs

Figure 7. Distribution of coal from Rocky Mountain states, by state of destination, 1975 (000 tons)




NC = Northern Colorado
SC = Southern Colorado
NM = New Mexico
U = Utah
T = Total coal delivered from the above states

Source: U.S. Bureau of Mines
Minerals Industry Survey (33)

are estimated based on the variables. (Table 6) Study of the several BOM reports leads to the conclusion that (1) there are economies of size. As a rule, the larger the annual mine output, the lower the total operating costs per ton of coal mined; and, (2) the stripping ratio is an important element in determining the mining costs. In general, the lower the stripping ratio the lower the unit cost of mined coal.

However, model mine cost budgeting is a site cost technique. It requires detailed, engineering knowledge of mining and is not easily adaptable for assessment of mining costs for the large number of actual and potential mine sites in the RM. Thus, it is not suitable for estimating regional averages. An appropriate way to obtain an area-wide average cost is to employ the statistical estimating technique of regression analysis. 7/

There tends to be a close relationship between coal prices, f.o.b. the mines, and mining costs; at least the differences between f.o.b. coal prices should reflect very closely the differences in mining costs. Since f.o.b. prices and stripping ratios are known for most counties, statistical relationships between f.o.b. prices and stripping ratios can be estimated. Then, using these relationships when only stripping ratios are known, average f.o.b. prices can be estimated, even on a site-specific basis. Average mining costs for each of the CPA's are estimated this way. These estimates show that, within the RM, 1975 costs per ton of coal were lowest in NM-1 (about $3.30 per ton) and highest in CO-4 ($5.90 per ton).

7/ Melvin Skold, Agricultural Economist, Natural Resource Economics Division, ESCS, USDA, performed the following regression analysis summarized on this page. His analysis is reported in full in the Appendix.

Table 6 Estimated annual operating cost for a hypothetical 5 million ton per year surface mine in the Rocky Mountain Region. (1972 dollars)

| | Total annual cost | Cost per ton |
|---|---|---|
| Direct cost: | | |
| Production: | | |
| Labor | $783,900 | $0.15 |
| Supervision | 183,000 | .04 |
| Subtotal | 966,900 | .19 |
| Maintenance: | | |
| Labor | 233,700 | .04 |
| Supervision | 27,000 | .01 |
| Subtotal | 260,700 | .05 |
| Total direct labor | $1,227,600 | .24 |
| Operating supplies: | | |
| Spare parts | 2,000,000 | .40 |
| Explosives | 678,000 | .14 |
| Lubrication | 70,000 | .01 |
| Diesel fuel | 125,000 | .02 |
| Tires | 175,000 | .04 |
| Miscellaneous | 250,000 | .05 |
| Total operating supplies | $3,298,000 | .66 |
| Power | 800,000 | .16 |
| Union welfare | 2,000,000 | .40 |
| Royalty | 875,000 | .18 |
| Payroll overhead | 429,700 | .08 |
| Subtotal | $4,104,700 | .82 |
| Total direct cost | $8,630,300 | 1.72 |
| Indirect cost: 15 percent of labor, maintenance, and supplies | 678,800 | .14 |
| Fixed cost: | | |
| Taxes and insurance (2% of plant cost) | 521,200 | .10 |
| Depreciation | 1,484,100 | .30 |
| Deferred expenses | 716,400 | .14 |
| Total fixed cost | 2,721,700 | .54 |
| Total annual production cost | 12,030,800 | 2.40 |

Source: Cost Analysis of Model Mines for Strip Mining of Coal in the United States. U.S. Bureau of Mines Information Circular 8535. 1972 (32)

Transportation costs of coal are a major determinant of a coal mine's market area. Transportation costs for coal shipped from the RM at times constitute over 50 percent of the total cost of the delivered product. Of 1975 RM coal output, 8 percent (raw tonnage) went to mine mouth generating plants while 68 percent was shipped by rail. Colorado was the largest user of rail shipment, moving 87 percent of its coal that way. About 72 percent of Utah's coal was moved by rail with 15 percent going to mine mouth plants. Most of Utah's remaining coal was hauled by truck. In Arizona, 40 percent was shipped by rail with the remaining 60 percent transported through the Black Mesa coal pipeline. Data on 1975 coal shipment for New Mexico were not available. However, in 1974, about 93 percent went to mine mouth plants.

In Midwest markets such as Chicago, RM coal is at a locational disadvantage vis-a-vis Eastern or Interior coal; it is 1,538 miles Black Mesa-Chicago, compared to 468 miles Pittsburgh-Chicago. Major factors affecting rail transport costs are (1) distance, (2) size of shipment, (3) type of equipment, unit or conventional. Typical shipping rates for coal from the RM in 1973 ranged from 4.5 cents per ton mile for 22 miles to .52 cents per ton mile moving 1,100 miles. (Table 7) Economies of haul are generally realized with increases in shipping distance, train load, and annual tonnage. In 1975, unit train shipments comprised 58 percent of all rail shipments from RM mines.

Because of the differing heat values among RM coals, transportation costs of energy are highest for the lower-energy sub-bituminous coal and lowest

Table 7.—Transportation cost characteristics of rail shipments of coal from the Rocky Mountain Region.

| Origin point | Consumption point | Shipping distance | Minimum trainload tonnage | Annual tonnage | Cost per ton mile |
|---|---|---|---|---|---|
| | | Miles | - - - Thousand tons - - - | | Cents |
| Northern Colorado | Utah | 351 | 3 | 1,300 | .88 |
| Northern Colorado | Utah | 360 | 3 | 350 | .77 |
| Southern CO and Northern N. Mex. | Colorado | 110 | - | 75 | 1.82 |
| Southern CO and Northern N. Mex. | Colorado | 214 | - | 1,250 | 1.34 |
| Southern CO and Northern N. Mex. | Colorado | 22 | - | - | 4.50 |
| Southern CO and Northern N. Mex. | Colorado | 16 | - | - | 3.43 |
| New Mexico and Ariz. | Arizona | 109 | - | 310 | 2.31 |
| New Mexico and Ariz. | California | 1,100 | 6 | 500 | .72 |
| New Mexico and Ariz. | California | 1,100 | - | 700 | .62 |
| New Mexico and Ariz. | California | 1,000 | - | - | .52 |
| Utah | Utah | 128 | 3 | 1,300 | .88 |

Source: U.S. Bureau of Mines Information Circular 8614. Comparative Transportation Costs of Supplying Low Sulfur Fuels to Midwestern and Eastern Domestic Energy Markets. (16)

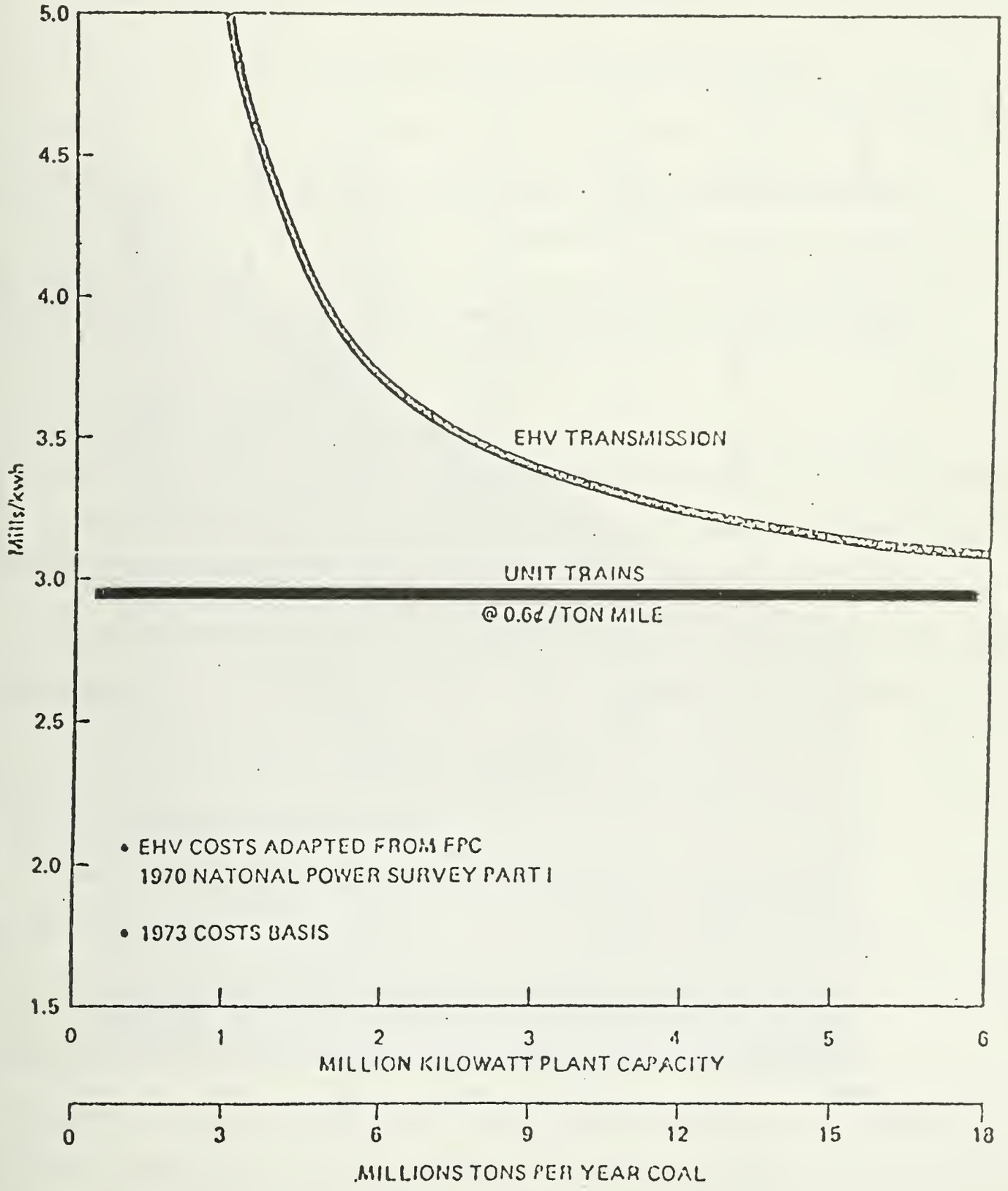
for the higher-energy bituminous. When viewed from the standpoint of transmitting energy, transmission costs from minemouth generating plants in the form of electricity can be compared with the cost of transporting the coal.

One theoretical engineering study compared likely costs of transmitting extra high voltage electricity vs. transporting coal by unit train for an energy transmission distance of 1,000 miles. Comparisons were made between the costs of the two transmission modes in transferring energy (that is, the equivalent electrical energy contained in coal) for quantities of this equivalent contained in 3 million tons of coal per year, ranging to the equivalent of 18 million tons. Only for the extremely large electricity transfer quantities of 15 to 18 million tons of coal equivalent per year was extra high voltage transmission able to display economies of scale sufficient to bring per unit energy transmission costs to the cost level maintained by unit trains. (Figure 8)

Usage by Electric Utilities

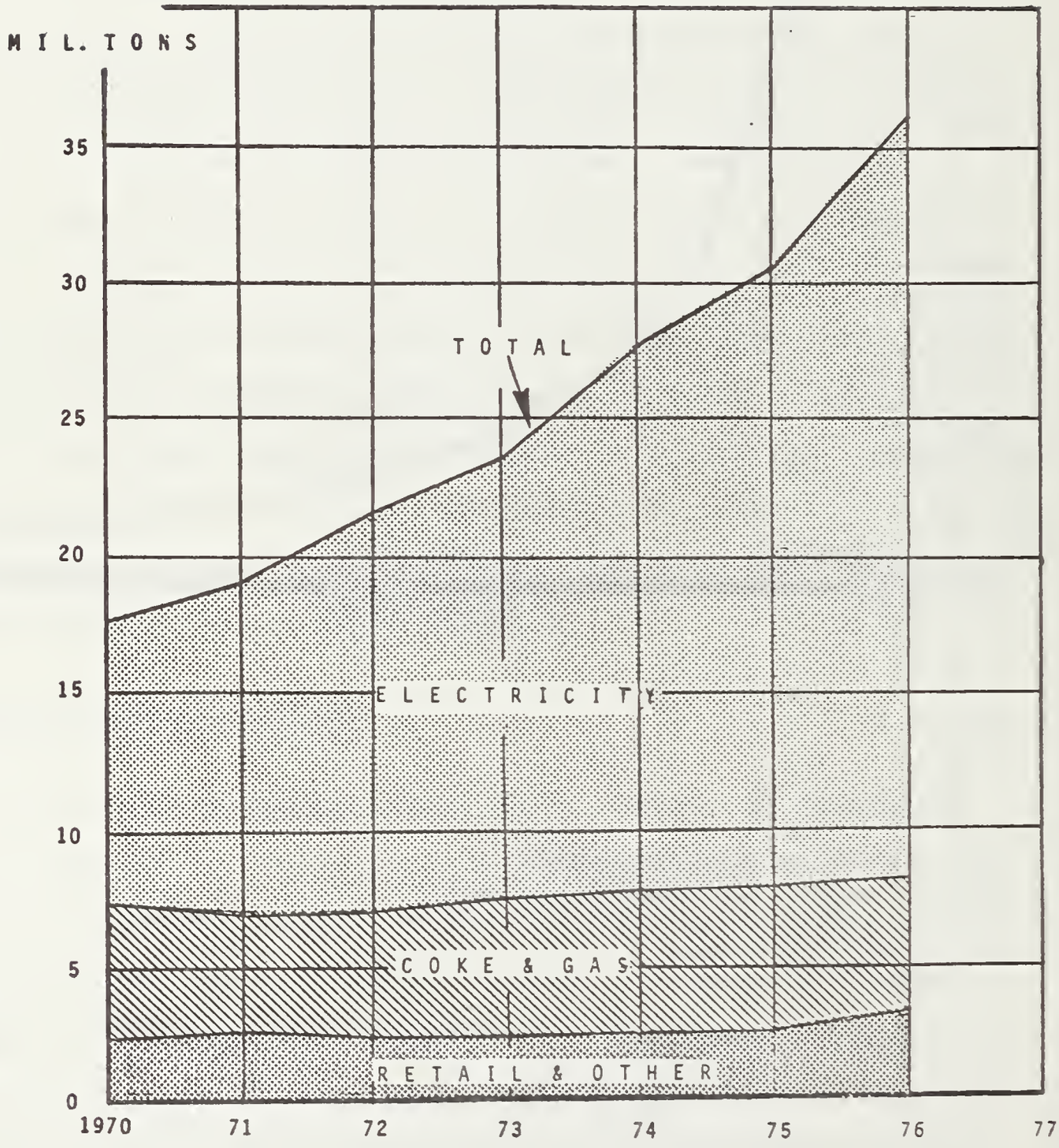
The new air quality standards (Clean Air Act) and the continued growth in the demand for electricity are the main forces behind the recent surge in coal development. About 80 percent of all RM coal is used to generate electric power. (Figure 9) Although growth of electric utility demand outside the RM has had some influence, the key impetus behind RM coal development stems from greater electric utility demand within the region. Several large, new, steam-electric plants of over 100 megawatt size have been brought "on line" in the RM since 1970. As of 1976, there were 21 electric power generating plants in the RM using coal as the sole or a

FIGURE 8. COST COMPARISONS OF ALTERNATIVE MODES OF COAL ENERGY TRANSMISSION (for 1,000-mile transport distances).




Source: National Academy of Engineering: U.S. Energy Prospects: an Engineering Viewpoint. (18)

FIGURE 9. CONSUMPTION & END USE OF ROCKY MOUNTAIN COAL, 1970-1976



significant source of fuel. Coal use per plant ranged from 5,000 to 6,756 tons annually, while output capacity ranged from 7.5 to 2,315 megawatts. (Table 8)

Coal production costs (mine mouth) in RM are lower in comparison with costs of midwestern or eastern coal. (See previous section on mining costs). This is an initial competitive advantage for RM coal, before calculating transportation costs to any given consumption point. The initial advantage is reinforced because of the available reserves of SO2 compliance coal.

Further analysis of the competitive position of RM coal in the U.S. markets is beyond the scope of this report, but will be undertaken by the Inter-regional Coal Analysis Model referred to in the Introduction. The key roles played by transportation costs and capacities as well as public policy in determining this competitive position can be addressed through quantitative techniques.

Projections and Future Plans

Projections of the electric utility component of total demand for RM coal have been made by the Bureau of Mines, based on known conditions. Demand for electricity coal from the RM is projected to increase between 1975-1983, from 20 million to about 55 million tons. (34)

However, factors not tied to the mining process could easily change some of these conditions. For example, federal sulfur dioxide emission standards or other air quality standards could be revised again, as they were in 1977.

Table 8.--Coal-fired electric power generating plants in the Rocky Mountains, 1975

| State and company | Plant name and location | Capacity | Coal used | |
|---|---|---|---|---|
| | | | Quantity | Pct. of total fuel used |
| | | Megawatts | Tons | Percent |
| Arizona | | | | |
| Arizona Public Service | Cholla Plant Joseph City, AZ. | 293 | 434,000 | 99.7 |
| Salt River Project | Navajo Plant Page, AZ. | 1,500 | 3,829,000 | 98.2 |
| Colorado | | | | |
| Colorado Springs Dept. of Public Utilities | Drake Steam Plant Colorado Springs, CO. | 353 | 728,000 | 85.6 |
| Colorado Ute. Electric Assn., Inc. | Nucla Plant Nucla, CO. | 39 | 90,200 | 100.0 |
| Colorado Ute. Electric Assn., Inc. | Hayden Plant Hayden, CO. | 190 | 1,029,000 | 99.6 |
| Colorado Ute. Electric Assn., Inc. | Bullock Plant Montrose, CO. | 12 | 32,000 | 99.4 |
| Public Service of Colorado | Valmont Steam Plant Boulder, CO. | 247 | 300,000 | 43.0 |
| Public Service of Colorado | Arapahoe Steam Plant Denver, CO. | 236 | 662,000 | 72.0 |
| Public Service of Colorado | Cherokee Steam Plant Denver, CO. | 706 | 1,780,000 | 86.6 |
| Public Service of Colorado | Cameo Steam Plant Cameo, CO. | 75 | 162,000 | 58.0 |
| Public Service of Colorado | Comanche Plant Pueblo, CO. | 660 | 2,446,000 | 100.0 |
| Soutnern Colo. Power Central Telephone and Uti. | W.N. Clark City Plant Canon City, CO. | 43 | 111,000 | 59.0 |
| Walsenburg Utilities | Walsen Plant Walsenburg, CO. | 11 | 20,000 | 100.0 |
| New Mexico | | | | |
| Arizona Public Service Co. | Four Corners Plant Fruitland, NM. | 2,315 | 6,756,000 | 99.5 |
| Public Service Co. of New Mexico | San Juan Plant Waterflow, NM. | 330 | 1,008,400 | 99.4 |
| Raton Public Service Co. | Raton Plant Raton, NM. | 12 | 25,000 | 100.0 |
| Utah | | | | |
| California Pacific Utilities Co. | Cedar Stream Plant Cedar City, UT | 7.5 | 5,000 | 100.0 |
| Utah Power and Light Co. | Gadsby Plant Salt Lake City, UT | 265.8 | 427,000 | 76.4 |
| Utah Power and Light Co. | Carbon Steam Plant Castel Gate, UT | 166 | 440,000 | 100.0 |
| Utah Power and Light Co. | Hale Plant Orem, UT | 64.5 | 97,000 | 95.8 |
| Utah Power and Light Co. | Huntington Canyon Plant Huntington, UT | 430 | 1,054,000 | 99.5 |

Source: Keystone Coal Industry Manual, 1977; Steam Electric Plant Factors, 1976, National Coal Association. (15,19)

Therefore, the quantity of RM coal demanded within the region as well as in other regions could be sharply affected compared to a situation without change in emission standards. In addition, other actions in the near future could affect the pace at which a coal gasification industry may develop.

Gasification could be a major user of RM coal. Deregulation of natural gas prices would be one of these actions. Different patterns of coal transportation via rail or slurry pipeline might develop in response to various constraints and demand patterns. The pricing of natural gas, even if not deregulated, is also extremely important since coal and natural gas are substitutable in certain uses, especially medium to long term. All these actions and factors could come together in complex forms, which can be analyzed in the context of an econometric model.

Projections being made for 1984 have the advantage of taking account of implementation of actual plans for new electrical generating capacity. Lead times may be 8 years, sometimes longer. In the RM, twenty-four additional coal fired plants are under construction, planned or proposed calling for electricity output ranging from 175 to 750 megawatts and using 550,000 to 2,270,000 tons of coal each, annually, when and if all planned units of each plant are completed. If current plans materialize, all 24 plants would be fully completed during the 1976-1984 period. (Table 9) Also, engineering plans for gasification and liquefication plants in the RM have been prepared by several companies. However, firm decisions to construct any of them on a commercial basis have not yet been made.

Table 9.--Projected coal-fired power-generating plants for the Rocky Mountains, as of 1976

| State and Company | Plant name or Location | Unit ID | Capacity | Due on Stream | Coal Demand | |
|---|---|---|---|---|---|---|
| | | | | | 1980 | 1985 |
| | | | Megawatts | Date | Thous. tons | |
| **Arizona** | | | | | | |
| Salt River Project | Navajo | #3 | 750 | 4/76 | 2270 | 2270 |
| Salt River Project | Coronado | #1 | 350 | 4/79 | 1100 | 1100 |
| Salt River Project | Coronado | #2 | 350 | 4/80 | 1100 | 1100 |
| Arizona Pub. Ser. Co. | Cholla | #2 | 250 | 6/78 | 740 | 740 |
| Arizona Pub. Ser. Co. | Cholla | #3 | 350 | 6/79 | 740 | 740 |
| Arizona Pub. Ser. Co. | Cholla | #4 | 350 | 6/80 | 1035 | 1035 |
| Arizona Electric Pur. Coop. | Apache | #2 | 175 | 10/78 | 550 | 550 |
| Arizona Electric Pur. Coop. | Apache | #3 | 175 | 4/79 | 550 | 550 |
| Tucson Gas and Electric Co. | Springerville | #1 | 330 | 6/84 | 0 | 1000 |
| **Colorado** | | | | | | |
| Colorado Ute | Hayden | #2 | 250 | 7/76 | 877 | 877 |
| Colorado Ute | Craig | #1 | 380 | 4/78 | 1200 | 1200 |
| Colorado Ute | Craig | #2 | 380 | 4/79 | 1200 | 1200 |
| Public Service Co. of Colorado | Pawnee | #1 | 500 | 4/79 | 1729 | 1729 |
| Public Service Co. of Colorado | Southeastern | #1 | 500 | 4/83 | 0 | 1730 |
| City of Colorado Springs | Nixon | #1 | 200 | 6/80 | 409 | 899 |
| **New Mexico** | | | | | | |
| Public Service Co. of New Mexico | San Juan | #1 | 326 | 12/76 | 1320 | 1416 |
| Public Service Co. of New Mexico | San Juan | #2 | 466 | 5/79 | 1900 | 2017 |
| Public Service Co. of New Mexico | San Juan | #4 | 466 | 5/81 | 0 | 2017 |
| Plains Electric G & T | Plains | #1 | 350 | 1/82 | 0 | 1035 |
| **Utah** | | | | | | |
| Utah Power & Light | Huntington Canyon | #1 | 415 | 6/77 | 800 | 800 |
| Utah Power & Light | Emery | #1 | 400 | 6/78 | 800 | 800 |
| Utah Power & Light | Emery | #2 | 400 | 4/80 | 800 | 800 |
| Nevada Power & Light | Warner Valley | #1 | 250 | 6/81 | 0 | 1419 |
| Nevada Power & Light | Warner Valley | #2 | 250 | 6/82 | 0 | 1419 |

Source: Federal Power Commission. Status of Coal Supply Contracts for New Electric Generating Units. (10)

# LAND

by
Wallace McMartin

## AREA

The total area of the four States in the Rocky Mountain Region is 424,738 square miles or about 272 million acres. The land area, excluding water surface, is about 269 million acres. The 15 Coal Production Areas (CPA's), consisting of 40 counties, embrace a total area of 91 million acres, about 1/3 of the land surface of the four States. The largest CPA is AZ-1 with 25.4 million acres; the smallest is CO-2 with one million acres. (Figure 10)

## SETTLEMENT HISTORY

The settlement history of the region helps to explain the origin of some of the unusual patterns of land ownership and land use. Most of the early exploration was by Spanish soldiers and priests, who came to the region through Mexico long before the English and French founded the colonies on the Atlantic seaboard. The Spanish influence was felt in all of what is now New Mexico, in all of Arizona except the part north of the Grand Canyon, and in Southern Colorado. When these areas were ceded to the United States by Mexico in 1848, land then in private ownership remained private; the rest became public domain. Settlement in Utah and northern Colorado did not begin until about the middle of the 19th Century, and then most of the explorers and settlers came from the East.

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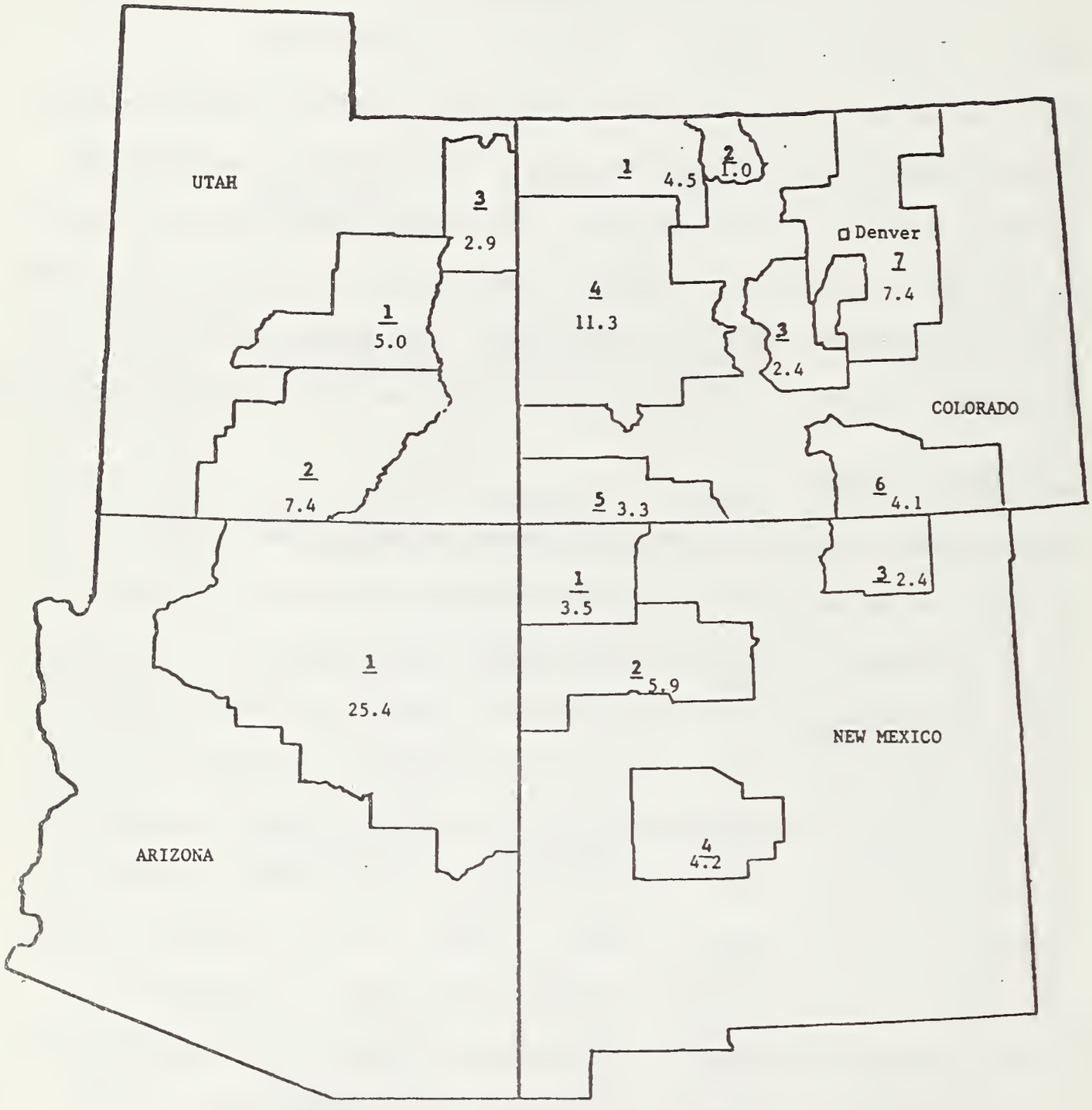
McMartin is an Agricultural Economist, Natural Resource Economics Division, ESCS, USDA. He prepared this section, "Land," under the title: "The Land Resource in the Coal Production Areas in the Rocky Mountain Region."

FIGURE 10. COAL PRODUCTION AREAS IN THE ROCKY MOUNTAIN REGION




Top numbers, underlined, designate CPA number.
Lower number, indicates land area, in millions of acres.

In Colorado, many of the early settlers were miners and prospectors; ranchers and farmers came later. Utah was settled largely by Mormon people, who sought a way of life based on farming. They settled mainly in areas where water was available for irrigation.

Throughout the region most of the land owned by private individuals was obtained from the United States under the provisions of the Homestead Act of 1862 and succeeding acts and amendments. Early settlers looked for land that was favorably located with respect to irrigation water, because in most of the region farming was not possible without it. If water was lacking, they looked for land that could be dry-farmed, or land that had drinking water available. The land could then be used as headquarters for a livestock ranch. Land without such advantages was ignored by settlers, and remained in public ownership. Later, the Federal Government made grants of land to States and certain railroads. The land for such grants was selected for a specified distance from the right of way of the main line, while grants made to the States for schools were usually two, three, or four even-numbered sections (of one square mile each) out of every township. Both railroads and the States sought to sell off their grant lands for agricultural purposes whenever possible, but only the most desirable parcels were saleable. Thus, a pattern emerged characterized by private ownership of level land along river valleys with public ownership in the mountainous or desert areas.

Large blocks of land were established as Indian reservations during the latter half of the 19th Century. Here the title to the land was held

in trust by the Federal Government, either for the tribe or as allotments for individual Indians. Most of the land set aside for Indian reservations in this region was not suited for agriculture and had not appealed to either farmers or ranchers. Thus, there is little or no non-Indian land within the boundaries of the reservations.

A number of National Forests were established by setting aside large blocks of public land, most of which was not occupied by settlers because it was rough, mountainous, and covered with timber. National parks and monuments were established to preserve for public use a number of areas with outstanding scenic or historical value.

LAND OWNERSHIP PATTERNS

The present ownership pattern is the composite result of many decisions by private individuals and by governments. The pattern is not consistent throughout the region, yet there are some similarities. In the CPA's as a group, the Federal Government is the dominant owner, with over 37 million acres or 41.2 percent of the total area. Indians own 21.8 percent and the States own 6.4 percent, leaving 30.6 percent in private ownership. (Table 10) Most of the Federal land is administered either by the Bureau of Land Management or by the Forest Service.

Within the CPA's the ownership patterns vary considerably. In two of them, NM-1 and AZ-1, well over half of the land is in Indian ownership, and almost half of NM-2 is Indian land. Federal agencies hold the major part of the land in all three of the Utah CPA's, as well as in CO-1, -2, and -4, and NM-4.

Table 10 Land Ownership in Coal Production Areas

| Coal production areas | Bureau of Land Management | Forest Service | National Park Service | Bureau of Reclamation | Fish and Wildlife Service | Military reserves | Other federal agencies | Indian land 1/ | State land 2/ | Private land 3/ | Total 4/ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1,000 acres | | | | | | | | | | |
| Arizona-1 | 813 | 4,363 | 866 | 98 | 0 | 29 | * | 13,495 | 2,218 | 3,475 | 25,357 |
| Colorado-1 | 1,533 | 625 | 151 | 47 | 12 | 0 | * | 0 | 257 | 1,901 | 4,526 |
| Colorado-2 | 196 | 334 | 0 | 0 | 12 | 0 | * | 0 | 123 | 373 | 1,038 |
| Colorado-3 | 425 | 751 | 0 | 5 | 0 | 0 | * | 0 | 159 | 1,043 | 2,383 |
| Colorado-4 | 4,057 | 3,814 | 31 | 161 | * | 56 | 2 | 16 | 12 | 3,170 | 11,319 |
| Colorado-5 | 229 | 1,061 | 52 | 24 | 0 | 0 | * | 766 | 19 | 1,139 | 3,290 |
| Colorado-6 | 86 | 214 | 0 | 0 | 0 | 0 | 3 | 0 | 227 | 3,545 | 4,075 |
| Colorado-7 | 19 | 531 | 25 | 1 | 0 | 183 | 63 | 0 | 481 | 6,130 | 7,433 |
| New Mexico-1 | 976 | 0 | 21 | * | 0 | 0 | * | 2,152 | 107 | 264 | 3,520 |
| New Mexico-2 | 826 | 579 | 22 | 0 | 0 | 0 | * | 2,824 | 223 | 1,394 | 5,868 |
| New Mexico-3 | * | 12 | 0 | 0 | 3 | 0 | * | 0 | 209 | 2,185 | 2,409 |
| New Mexico-4 | 947 | 631 | * | 4 | 279 | 323 | 4 | 63 | 485 | 1,490 | 4,226 |
| Utah-1 | 2,740 | 958 | 7 | 5 | 3 | 0 | * | 0 | 437 | 870 | 5,020 |
| Utah-2 | 4,070 | 1,329 | 337 | 690 | 0 | 0 | 1 | 0 | 580 | 384 | 7,391 |
| Utah-3 | 1,340 | 270 | 50 | 9 | 8 | 89 | * | 427 | 231 | 448 | 2,872 |
| Total | 18,256 | 15,471 | 1,563 | 1,044 | 316 | 680 | 73 | 19,743 | 5,767 | 27,815 | 90,728 |

* Less than 500 acres.
1/ Tribal land, allotments and U.S. government land administered by the Bureau of Indian Affairs.
2/ Mostly school grant land.
3/ All land except U.S., Indian, and state owned land.
4/ Land area excluding water surface.

Source: Compiled from (36) and from inventory records of federal agencies. Effective dates vary - most are for year ending June 30, 1975.

Each of the CPA's also includes State land, which ranges from 0.1 percent of the area in CO-4 to over 11 percent in CO-2 and NM-4.

Land not owned by the Federal Government, by the States, or by Indians is assumed to be private land. In two CPA's, NM-1 and UT-2, less than 10 percent of the total is in private ownership. The largest percentage of private land is in eastern Colorado, CO-6 and CO-7.

One of the largest private owners in AZ-1, NM-1, and NM-2 is Santa Fe Industries, the corporation which now owns the Atchison, Topeka and Santa Fe Railroad. During the time of railroad expansion the Santa Fe was one of the recipients of Federal land grants, typically every odd-numbered section for a specified distance from the right of way. The resulting checkerboard pattern of ownership still persists, even though much land was sold to individuals. In AZ-1, the tax records show that about 134,000 acres of land is still owned by railroads, the equivalent of about 4 percent of the private land in that particular CPA (1). In the Colorado and Utah CPA's, there is little or no railroad grant land.

MINERAL OWNERSHIP

The discussion thus far describes only the ownership of land surface, though the surface owner does not necessarily own the coal rights. Separation of mineral ownership from surface ownership is common in the case of privately owned land, and where such separation has occurred a complex patchwork of mineral ownership exists. However, on most of the Indian land, the mineral rights are owned by the tribal government. In

AZ-1 the coal rights in all the known coal fields are owned by Indian tribes. The two mines there are operated under contractual arrangements with the tribal government. In NM-1 and NM-2, most of the coal now being mined is owned by Indians. 1/

In general, where the Federal Government owns the surface it also owns the minerals. This is true of the public domain (administered by BLM) and the National Forests. On some land now owned by the Federal Government but formerly in private ownership, the title to the minerals may have been retained by the previous owner, but such cases are not common in the CPA's. On most State land the State owns the mineral rights.

Areas where minerals are owned by railroads, or otherwise privately owned, are often contiguous to holdings within the public domain. This type of ownership distribution makes administration of both private and public rights inextricably bound together. This pattern of land and mineral ownership leads to conflicting claims and interest, which could be a hindrance to coal development in the Rocky Mountain Region.

PHYSICAL CHARACTERISTICS OF THE LAND

Land forms in the Rocky Mountain Regions vary widely. There are jagged snow covered mountain peaks, canyons with fantastically carved walls, high plateaus and mesas, prairies which seem to stretch endlessly, and rivers that run through broad valleys dotted with farms and small towns.

1/ For a discussion of the special problems encountered in leasing Indian land, see (8).

Climate often varies with the landscape. Precipitation is least in the Southern parts of Arizona and New Mexico and in western Utah. Here, irrigation is necessary for crop production; without it the land is useful only for grazing. The plains of eastern Colorado and New Mexico get more rainfall; there, the climate is best described as semi-arid. Crops of wheat and grain sorghum can be produced on the better soils with normal rainfall and careful cultural practices, but where water is available farmers find it more profitable to irrigate. In the high mountains, precipitation is more generous, and the winter snow pack serves as a major source of run-off for the streams below.

Temperatures also vary widely in the region. Extremes of cold weather are generally encountered at high elevations and in the more northern locations. Extreme high temperatures are found at the lower elevations in the southernmost locations.

Elevations of the CPA's are all relatively high, the highest being CO-3, about 9,950 feet above sea level at the town of Fairplay; and CO-2, 8,100 feet at Walden. Mountain peaks higher than 10,000 feet occur in most of the CPA's. The lowest elevations are in CO-7 -- 4,490 feet at Masters in eastern Weld County. Since most of the area in the CPA's is a mile or more above sea level, the climate is moderately cold in winter; the growing seasons are short, dry, and frequently hot.

LAND USE

To a certain extent, the land ownership patterns suggest the general types of land uses. Land owned by the National Park Service (NPS) is

used exclusively for recreation. Mining on NPS land is usually prohibited. BLM and Forest Service land is used for forestry, grazing and recreation. Indian land is used primarily for agriculture, with extensive grazing the predominant pattern.

In the nine CPA's, there are about 48 million acres in farms, representing 52.7 percent of the total land area. (Table 11) 2/ However, about 44 million acres of the "farm" land, or 92 percent of it, is pasture and range. Four percent of the land, 3.7 million acres, is classified as cropland. Of this there were two million acres, or 54 percent, that were harvested for crops in 1969. In terms of total land in farms, AZ-1 is the largest, although almost all the land is rangeland, mostly of low carrying capacity. However, in terms of agricultural productive capacity, CO-7 dominates, with more cropland and harvested crops than all the other CPA's combined. CO-7, in turn, is dominated by Weld County, which has more cropland and more harvested crops than all the other counties in CO-7 combined. In most of the other CPA's, the type of agriculture is very extensive except where irrigation is practiced.

There is some irrigated land in each of the CPA's, though more than half is in CO-4 and CO-7. The smallest acreage of irrigated land is in NM-2, NM-3, and NM-4. In AZ-1, the largest CPA, there are 26,000 acres of irrigated land, but this represents only a small part of the land in farms.

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2/ In this section the term "farm" is used in its broadest sense to include all agricultural operating units, both farms and ranches, in accordance with the definition used in the U.S. Census of Agriculture, 1974. National Forest land grazed under permit is not included in the farm land acreage. However, Indian Reservations and certain grazing associations are included, and counted as though each one were a "farm".

Table 11 Land Area and Major Land Use, All Farms, 1974

| Coal producing areas | Land area | Non-farm land | Land in Farms | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Cropland | | | | Pasture range, & other | Total 1/ | Irrigated land 2/ |
| | | | Harvested | Pastured | Other | Total | | | |
| | 1,000 acres | | | | | | | | |
| Arizona-1 # | 25,357 | 6,164 | 25 | 24 | 25 | 74 | 19,119 | 19,193 | 26 |
| Colorado-1 # | 4,526 | 2,730 | 132 | 37 | 84 | 253 | 1,544 | 1,797 | 68 |
| Colorado-2 # | 1,038 | 567 | 75 | 18 | 2 | 95 | 376 | 470 | 91 |
| Colorado-3 | 2,383 | 1,612 | 26 | 11 | 7 | 44 | 727 | 772 | 41 |
| Colorado-4 # | 11,319 | 8,759 | 299 | 179 | 37 | 515 | 2,045 | 2,560 | 377 |
| Colorado-5 | 3,290 | 1,728 | 144 | 87 | 23 | 254 | 1,308 | 1,562 | 116 |
| Colorado-6 | 4,075 | 1,247 | 44 | 32 | 30 | 106 | 2,722 | 2,829 | 22 |
| Colorado-7 | 7,433 | 1,639 | 1,072 | 217 | 649 | 1,938 | 3,856 | 5,794 | 463 |
| New Mexico-1 # | 3,520 | 1,608 | 22 | 13 | 4 | 39 | 1,873 | 1,912 | 29 |
| New Mexico-2 # | 5,868 | 1,715 | 8 | 13 | 16 | 39 | 4,116 | 4,153 | 9 |
| New Mexico-3 | 2,409 | 140 | 17 | 30 | 16 | 63 | 2,206 | 2,269 | 13 |
| New Mexico-4 | 4,226 | 2,328 | 13 | 11 | 5 | 29 | 1,869 | 1,898 | 16 |
| Utah-1 # | 5,020 | 4,239 | 60 | 38 | 8 | 106 | 676 | 782 | 82 |
| Utah-2 # | 7,391 | 6,958 | 23 | 26 | 4 | 53 | 380 | 433 | 34 |
| Utah-3 | 2,872 | 1,464 | 31 | 26 | 16 | 73 | 1,335 | 1,408 | 52 |
| Total 1/ | 90,728 | 42,896 | 1,991 | 762 | 926 | 3,679 | 44,153 | 47,832 | 1,436 |
| Percent of Total | 100.0 | 47.3 | 2.2 | 0.8 | 1.0 | 4.1 | 48.7 | 52.7 | 1.6 |

# Indicates CPA's with significant strippable reserves of coal.
1/ Detail may not add to totals due to rounding.
2/ Included in total column.
Compiled from U.S. Census of Agriculture, Volume 1. (26)

In AZ-1, 75.7 percent of the land area was in farms but only 0.4 percent of the farmland was cropland, and only 33.8 percent of the cropland was harvested. In NM-3 and NM-2, the situation was similar. A large percentage of land was in farms; only a very small part of the farmland was cropland and only a small part of the cropland was harvested. In UT-2 and UT-1, only a small part of the land area was farmland —5.9 percent and 15.6 percent, respectively. The ratio of cropland to farmland was highest in CO-7 and lowest in the Arizona and New Mexico CPA's.

NUMBER AND SIZE OF FARMS

In the 15 CPA's, there were over 16,000 farms, which averaged 2,986 acres in size, though the average cropland per farm was 230 acres. (Table 12) Without further explanation, such averages would be misleading because they combine two dissimilar groups, the "Farms over $2,500" and "Other farms". 3/

In most areas the farms over $2,500 are considered to be most nearly representative of the normal farm situation. In the 15 CPA's, there are 11,794 farms over $2,500 with an average size of 2,171 acres, of which 286 acres are cropland.

There are large differences in average size between the over $2,500 farms and "Other" farms. (Table 12) In AZ-1, NM-1, NM-2, UT-3, the "Other farms" average much larger than the over $2,500 group, but in all the other CPA's they average much smaller. This is because the "Other farms" are made

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3/ In the 1974 Census of Agriculture, farms were reported in two categories, those with more than $2,500 gross sales of farm products, and "Other farms." "Other farms" consist of two groups: (1) those with less than $2,500 gross sales and (2) "abnormal" farms which include experimental and institutional farms as well as Indian reservations and grazing associations. Detailed data are not tabulated separately for the latter two groups.

Table 12 Number of Farms and Average Size, Farms Over $2,500 and all Others, 1974 1/

| Coal production areas | Number of Farms | | | Land in Farms 2/ | | | Average Size | | | Average Cropland per Farm | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | All farms | Over $2,500 | Other | All farms | Over $2,500 | Other | All farms | Over $2,500 | Other | All farms | Over $2,500 | Other |
| | number | | | 1,000 acres | | | acres | | | acres | | |
| Arizona-1 | 558 | 364 | 194 | 19,194 | 4,827 | 14,367 | 34,397 | 13,260 | 74,056 | 133 | 78 | 237 |
| Colorado-1 | 521 | 473 | 48 | 1,797 | 1,760 | 37 | 3,449 | 3,721 | 766 | 485 | 526 | 87 |
| Colorado-2 | 92 | 87 | 5 | 470 | 400 | 71 | 5,114 | 4,592 | 14,191 | 1,029 | 1,081 | 126 |
| Colorado-3 | 324 | 208 | 116 | 772 | 677 | 95 | 2,381 | 3,254 | 817 | 137 | 181 | 57 |
| Colorado-4 | 3,573 | 2,460 | 1,113 | 2,560 | 2,459 | 100 | 716 | 1,000 | 90 | 144 | 203 | 14 |
| Colorado-5 | 1,215 | 772 | 443 | 1,562 | 668 | 894 | 1,286 | 865 | 2,019 | 209 | 284 | 79 |
| Colorado-6 | 608 | 442 | 166 | 2,829 | 2,680 | 148 | 4,652 | 6,064 | 894 | 175 | 201 | 106 |
| Colorado-7 | 5,993 | 5,006 | 987 | 5,794 | 5,567 | 228 | 967 | 1,112 | 231 | 323 | 376 | 57 |
| New Mexico-1 | 407 | 200 | 207 | 1,912 | 173 | 1,739 | 4,698 | 865 | 8,401 | 95 | 116 | 75 |
| New Mexico-2 | 362 | 195 | 167 | 4,153 | 1,035 | 3,118 | 11,472 | 5,307 | 18,671 | 102 | 74 | 134 |
| New Mexico-3 | 265 | 202 | 63 | 2,269 | 2,100 | 169 | 8,561 | 10,396 | 2,676 | 238 | 272 | 129 |
| New Mexico-4 | 321 | 215 | 106 | 1,898 | 1,806 | 92 | 5,914 | 8,402 | 867 | 91 | 115 | 42 |
| Utah-1 | 929 | 665 | 264 | 782 | 731 | 51 | 841 | 1,098 | 194 | 114 | 142 | 41 |
| Utah-2 | 438 | 206 | 232 | 433 | 326 | 107 | 988 | 1,582 | 461 | 121 | 218 | 35 |
| Utah-3 | 413 | 299 | 114 | 1,408 | 398 | 1,010 | 3,409 | 1,332 | 8,857 | 177 | 163 | 213 |
| Total/Average | 16,019 | 11,794 | 4,225 | 47,832 | 25,606 | 22,226 | 2,986 | 2,171 | 5,261 | 230 | 286 | 72 |

1/ Other farms include those classified as "abnormal". See text.
2/ Detail may not add due to rounding.

Compiled from U.S. Census of Agriculture, Volume 1. (26)

made up of two mismatched groups, "abnormal" farms and farms whose sales were less than $2,500. (Footnote 3/)

Most of the "abnormal" farms are very large in size, because they include Indian reservations, located principally in AZ-1, NM-1, and NM-2. For example, five of the "Other farms" in NM-1 are classified as "abnormal", among them occupying about 1.7 million acres of land, an average of 345,000 acres each. 4/ In AZ-1 and NM-2 respectively, 75 and 90 percent of the farm land is in "Other farms."

The rest of the "Other farms" group, those with gross sales of less than $2,500, tend to be very small in acreage. In most CPA's where there is little or no Indian land, the "Other farms" category is composed mainly of these small farms. Thus, the "Other" category tends to contain only a small fraction of the total land in farms where there are no Indian reservations.

There is a large variation among CPA's in the amount of cropland on the over $2,500 farms; the average is 1,081 acres in CO-2 and 526 acres in CO-1. In the other CPA's, the averages are much less -- 74 acres in NM-2 and 78 acres in AZ-1.

CROP ACREAGE

CO-7 is the richest agricultural area of the region. It has more than a million acres of cropland harvested, which is more than all the other CPA's combined. (Table 11) Half of the cropland harvested is

4/ The size of the "abnormal" farms is not reported separately by the Census but an approximation can be derived from the frequency distribution by size groups (26), County Table 1).

wheat, but there are substantial acreages of corn and hay. (Table 13) Sugar beets, sorghum, and barley are also grown in lesser amounts. In most of the other CPA's, alfalfa and other hay are the principal crops, though significant acreages of wheat are found in CO-1 and CO-5.

## THE IMPORTANCE OF IRRIGATION

Irrigation is necessary for the production of most crops in all of the CPA's except CO-7, where a combination of favorable precipitation and good quality soils make dry land wheat production profitable. Even there, a large amount of irrigation is practiced; 40 percent of the cropland harvested in CO-7 is irrigated. In five of the CPA's 90 percent or more of the harvested cropland is irrigated, as follows:

| CPA | Percent | CPA | Percent |
|---|---|---|---|
| AZ-1 | 90 | NM-1 | 98 |
| | | NM-2 | 62 |
| CO-1 | 41 | NM-3 | 73 |
| CO-2 | 88 | NM-4 | 83 |
| CO-3 | 84 | | |
| CO-4 | 90 | UT-1 | 92 |
| CO-5 | 35 | UT-2 | 96 |
| CO-6 | 44 | UT-3 | 89 |
| CO-7 | 40 | | |
| | | Average | 53 |

All the sugar beets and potatoes are irrigated, and most of the corn and alfalfa. Wheat, though, is mostly produced without irrigation. The principal crops and the percent irrigated are as follows:

| Crops | Percent | Crops | Percent |
|---|---|---|---|
| Sugar beets | 100 | Other hay | 76 |
| Potatoes | 100 | Oats & barley | 65 |
| Corn | 97 | Sorghum | 29 |
| Alfalfa | 84 | Wheat | 4 |

Table 13 Acres of Principal Crops, by Coal Production Areas, 1974 1/

| Coal production areas | Wheat | Oats | Barley | Alfalfa hay | Other hay | Irish potatoes | Sugar beets | Corn | Sorghum | Dry field beans | All other crops 2/ | Total cropland harvested | Cropland pastured | All other cropland | Total cropland |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | acres | | | | | | | | | | | | | | |
| Arizona-1 | 295 | 0 | 0 | 3,798 | 2,579 | 1 | 0 | 675 | 1,057 | 9 | 203 | 8,617 | 16,301 | 3.397 | 28.315 |
| Colorado-1 | 37,169 | 1,608 | 6,404 | 24,428 | 41,286 | 12 | 0 | 474 | 60 | 0 | 140 | 131,301 | 34,136 | 83,268 | 248,705 |
| Colorado-2 | 0 | 0 | 0 | 2,093 | 73,224 | 0 | 0 | 0 | 0 | 0 | 0 | 75,317 | 17,197 | 1,548 | 94,062 |
| Colorado-3 | 330 | 77 | 0 | 3,810 | 19,239 | 1 | 0 | 338 | 0 | 0 | 305 | 24,100 | 6,907 | 6,654 | 37,691 |
| Colorado-4 | 16,890 | 3,736 | 18,807 | 98,401 | 87,546 | 348 | 7,659 | 32,165 | 478 | 6,329 | 12,778 | 285,137 | 154,718 | 29,915 | 469,770 |
| Colorado-5 | 35,553 | 1,278 | 2,250 | 25,197 | 17,586 | 122 | 0 | 2,596 | 60 | 46,438 | 104 | 131,184 | 67,185 | 20,550 | 218,919 |
| Colorado-6 | 14,355 | 525 | 316 | 19,205 | 3,975 | 0 | 0 | 917 | 2,190 | 0 | 459 | 41.942 | 20,137 | 26,734 | 88,813 |
| Colorado-7 | 530,233 | 7,230 | 44,994 | 136,722 | 65,562 | 3,335 | 40,347 | 188,226 | 14,582 | 19,444 | 10,653 | 1,061,328 | 181,458 | 638,663 | 1,981,449 |
| New Mexico-1 | 229 | 129 | 88 | 7,038 | 632 | 60 | 0 | 1,325 | 77 | 90 | 361 | 10,029 | 10,148 | 3,035 | 23,212 |
| New Mexico-2 | 162 | 0 | 0 | 980 | 375 | 0 | 0 | 13 | 100 | 0 | 880 | 2,510 | 9,775 | 2,181 | 14,466 |
| New Mexico-3 | 1,218 | 355 | 87 | 7,703 | 5,635 | 0 | 0 | 239 | 20 | 0 | -22 | 15,235 | 24,241 | 15,489 | 54,965 |
| New Mexico-4 | 70 | 0 | 83 | 6,630 | 793 | 0 | 0 | 1,909 | 2,459 | 143 | 446 | 12,533 | 6,957 | 5,310 | 24,800 |
| Utah-1 | 2,265 | 1,751 | 6,330 | 31,214 | 5,280 | 11 | 219 | 6,702 | 115 | 0 | 488 | 54,375 | 32,604 | 7,748 | 94,727 |
| Utah-2 | 814 | 471 | 2,064 | 13,927 | 2,486 | 112 | 0 | 640 | 0 | 0 | -88 | 20,426 | 21,260 | 3,233 | 44,919 |
| Utah-3 | 1,941 | 530 | 1,324 | 15,091 | 3,689 | 1 | 0 | 3,606 | 135 | 0 | 277 | 26,654 | 17,331 | 4,688 | 48,673 |
| Total | 661,524 | 17,750 | 82,747 | 396,237 | 329,887 | 4,003 | 48,225 | 239,825 | 21,333 | 72,453 | 26,704 | 1,900,688 | 620,355 | 852,443 | 3,373,486 |

1/ Includes only farms with over $2,500 gross farm sales.
2/ Includes allowance for double cropping.

Compiled from U.S. Census of Agriculture, Volume 1. (26)

Most of the irrigated land is used to support the livestock industry; 44 percent of it is used to produce hay, mostly alfalfa. (Table 14) In addition, 46 percent is used for feed grain and pasture, leaving only 10 percent of the irrigated land for food crops including wheat, sugar beets, potatoes, dry field beans, etc. Most of the food crop acreage is found in CO-4 and CO-7. In addition to the irrigated land, the irrigated farms have more than 10 million acres of non-irrigated land, most of which is dry pasture or range. In NM-3 the average irrigated farm has 13,800 acres of non-irrigated pasture and range; in CO-7 the average is 460 acres. 5/ The use patterns on the irrigated land and the fact that irrigated farms include large acreages of range land suggest that the irrigated land is very important as a feed base to support the livestock industry in each CPA.

## IRRIGATION PRACTICES AND WATER USE

The total water used in all CPA's was 2.8 million acre feet, an average of 2.1 acre feet per acre irrigated. (Table 15) The total quantity used was largest in CO-4 and CO-7, though the rate per acre was highest in UT-1 and NM-1. Most of the water is applied by surface methods; only 6.6 percent of the acres are irrigated by sprinklers. About half of the sprinkler irrigation is with self propelled units, though nearly all of these are located in CO-7. (26)

5/ Computed from data in Table 14.

Table 14 Land Use on Irrigated Farms, 1974 1/

| Coal production areas | Irrigated Land | | | | | | | | Land Not Irrigated | | | Number of irrigated farms |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Hay crops | Feed grains 2/ | Wheat | Sugar beets | Other crops 3/ | Harvested cropland | Pasture and other | Total 4/ | Cropland | Pasture and other | Total 4/5/ | |
| | 1000 acres | | | | | | | | | | | |
| Arizona-1 | 6 | 2 | * | 0 | * | 8 | 7 | 14 | 10 | 856 | 880 | 170 |
| Colorado-1 | 52 | 1 | 1 | 0 | * | 53 | 14 | 68 | 90 | 1,204 | 1,361 | 299 |
| Colorado-2 | 66 | 0 | 0 | 0 | 0 | 66 | 25 | 91 | 4 | 245 | 340 | 74 |
| Colorado-3 | 20 | * | * | 0 | * | 20 | 18 | 38 | 10 | 418 | 467 | 145 |
| Colorado-4 | 172 | 52 | 6 | 8 | 19 | 257 | 100 | 357 | 111 | 1,658 | 2,125 | 2,236 |
| Colorado-5 | 37 | 5 | 3 | 0 | 1 | 45 | 48 | 94 | 51 | 320 | 465 | 576 |
| Colorado-6 | 17 | 1 | * | 0 | * | 19 | 2 | 20 | 21 | 879 | 921 | 164 |
| Colorado-7 | 123 | 215 | 13 | 40 | 30 | 422 | 33 | 455 | 395 | 1,340 | 2,191 | 2,911 |
| New Mexico-1 | 8 | 2 | * | 0 | 1 | 10 | 5 | 15 | 7 | 131 | 153 | 170 |
| New Mexico-2 | 1 | * | 0 | 0 | * | 2 | 1 | 3 | 5 | 49 | 57 | 95 |
| New Mexico-3 | 10 | 1 | 1 | 0 | * | 11 | 1 | 12 | 24 | 1,105 | 1,141 | 80 |
| New Mexico-4 | 7 | 3 | * | 0 | 1 | 10 | 3 | 14 | 3 | 233 | 250 | 118 |
| Utah-1 | 34 | 14 | 2 | * | * | 50 | 25 | 75 | 23 | 520 | 618 | 580 |
| Utah-2 | 16 | 3 | 1 | 0 | * | 20 | 11 | 31 | 13 | 225 | 268 | 253 |
| Utah-3 | 17 | 6 | 1 | 0 | * | 24 | 18 | 42 | 13 | 262 | 317 | 276 |
| Total 4/ | 584 | 304 | 28 | 48 | 53 | 1,016 | 312 | 1,328 | 780 | 9,445 | 11,553 | 8,147 |
| Percent 6/ | 44.0 | 22.8 | 2.1 | 3.6 | 4.0 | 76.5 | 23.5 | 100.0 | | | | |

* Less than 500 acres.
1/ Includes all farms with irrigated land.
2/ Includes oats, barley, corn, and sorghum.
3/ Includes potatoes, dry field beans, and other crops, mostly food crops. May include an allowance for double cropping.
4/ Detail may not add to total because of rounding.
5/ Total of land in those farms that had some irrigated land.
6/ Percent of total irrigated land.

Compiled from U.S. Census of Agriculture, Volume 1. (26)

Table 15 Irrigation Water Used and Irrigation Methods, 1974

| Coal production areas | Irrigation Water Used | | Irrigation Method | | |
|---|---|---|---|---|---|
| | Total | Per acre | Furrows & ditches | Sprinklers | Other 1/ |
| | 1,000 acre feet | acre feet | percent | | |
| Arizona-1 # | 35 | 2.4 | 45.6 | 9.0 | 45.4 |
| Colorado-1 # | 124 | 1.8 | 35.5 | 2.7 | 61.8 |
| Colorado-2 # | 173 | 1.9 | 25.5 | * | 74.5 |
| Colorado-3 | 73 | 1.9 | 22.1 | 0.9 | 77.0 |
| Colorado-4 # | 901 | 2.5 | 59.5 | 2.3 | 38.2 |
| Colorado-5 | 214 | 2.3 | 65.0 | 2.8 | 32.2 |
| Colorado-6 | 38 | 1.8 | 29.7 | 2.3 | 68.0 |
| Colorado-7 | 824 | 1.8 | 58.9 | 12.2 | 28.9 |
| New Mexico-1 # | 45 | 2.9 | 77.2 | 15.6 | 7.2 |
| New Mexico-2 # | 6 | 2.3 | 31.3 | 0.5 | 68.2 |
| New Mexico-3 # | 19 | 1.5 | 20.5 | 4.9 | 74.6 |
| New Mexico-4 | 33 | 2.4 | 24.9 | 6.7 | 68.4 |
| Utah-1 # | 215 | 2.9 | 80.8 | 2.1 | 17.1 |
| Utah-2 # | 71 | 2.3 | 36.8 | 38.7 | 24.5 |
| Utah-3 | 75 | 1.8 | 57.1 | 2.4 | 40.5 |
| Total/Average | 2,847 | 2.1 | 54.5 | 6.6 | 38.9 |

\# Indicates CPA's where some surface mining is projected.
* Less than 0.05 percent.
1/ Mainly flooding, though small acreages of sub-irrigation may be included.

Compiled from U.S. Census of Agriculture, Volume 1. (26)

LIVESTOCK NUMBERS

Cattle are the most important class of livestock in the CPA's, with almost two million head, mostly beef breeds, with relatively few milk cows. (Table 16) CO-7 and CO-4 are the leading areas in cattle numbers — between them they account for more than half the cattle. Beef enterprises in this region are two types — ranch operation and feed lots. Weld County, in CO-7, is famous for its very large feedlots, some of them holding up to 140,000 head of cattle. 6/ Large scale sheep feeding enterprises are also common in CO-7. In the other CPA's, cattle are kept mostly on range-type pasture, and are marketed as grass fed beef. Large numbers of sheep are found in AZ-1, CO-1, -4, as well as CO-7.

As noted earlier, three of the CPA's have large acreage of Indian land, and the type of livestock operation is different in these areas. In AZ-1 more than a third of the cattle and 87 percent of the sheep are found on "Other farms", and most of these are on the units classified as "abnormal" — in this case grazing associations and Indian tribal holdings. In NM-1 the situation is similar — 39 percent of the cattle and 68 percent of the sheep are on "Other farms". In NM-2 nearly all the sheep (97 percent) are found on the "Other farms".

AGRICULTURAL INCOME

Gross income from the sales of farm products in 1974 was $967 million, of which $732 million or 76 percent, was from the sale of livestock and

6/ In Weld County there were 80 farms from which more than 500 head of grain fed cattle were sold. These farms sold 781,300 head, an average of 9,767 per farm. (26, County Table 7)

Table 16 Livestock Inventory, All Farms, 1974

| Coal production areas | Milk cows | Beef cows | All other cattle | Total cattle | Hogs and pigs | Sheep and lambs | Animal units |
|---|---|---|---|---|---|---|---|
| | Number of Head | | | | | | |
| Arizona-1 | 589 | 81,457 | 62,429 | 144,475 | 23,282 | 360,808 | 155,747 |
| Colorado-1 | 284 | 36,561 | 33,615 | 70,460 | 437 | 164,709 | 71,134 |
| Colorado-2 | 70 | 22,441 | 17,901 | 40,412 | 6 | 138 | 26,995 |
| Colorado-3 | 1,725 | 14,518 | 17,105 | 33,348 | 1,496 | 511 | 22,268 |
| Colorado-4 | 8,358 | 156,668 | 166,121 | 331,147 | 22,775 | 254,577 | 259,494 |
| Colorado-5 | 1,749 | 40,020 | 34,880 | 76,649 | 2,434 | 38,499 | 57,467 |
| Colorado-6 | 782 | 44,522 | 44,431 | 89,735 | 1,010 | 794 | 58,936 |
| Colorado-7 | 33,359 | 166,305 | 607,134 | 806,798 | 82,192 | 268,197 | 526,638 |
| New Mexico-1 | 360 | 11,955 | 10,986 | 23,301 | 887 | 42,183 | 21,922 |
| New Mexico-2 | 42 | 29,289 | 17,323 | 46,654 | 653 | 74,700 | 43,470 |
| New Mexico-3 | 210 | 26,858 | 31,697 | 58,765 | 713 | 1,138 | 37,858 |
| New Mexico-4 | 551 | 30,441 | 22,257 | 53,249 | 99 | 4,916 | 36,790 |
| Utah-1 | 2,605 | 31,129 | 45,381 | 79,115 | 1,881 | 57,667 | 59,225 |
| Utah-2 | 934 | 23,164 | 17,941 | 42,039 | 590 | 25,797 | 32,423 |
| Utah-3 | 1,072 | 24,220 | 23,750 | 49,042 | 2,371 | 25,381 | 36,604 |
| Total | 52,690 | 739,548 | 1,152,951 | 1,945,189 | 140,826 | 1,320,015 | 1,446,971 |

Compiled from U.S. Census of Agriculture, Volume 1. (26)

livestock products. (Table 17) The pattern is dominated by CO-7, which accounted for $725 million or 75 percent of total farm sales. Weld County produced $601 million in farm sales, or 62 percent of the total for all RM CPA's. A large part of the income in Weld County is from the sale of livestock -- mostly the cattle and sheep fattened in large feed lots. Weld County also dominates in crop sales, with $112 million, which is 47 percent of the total for all CPA's. (26)

Another important feature of the income pattern is the division between the farms over $2,500 and "Other farms". In AZ-1 the total farm sales were $26 million, of which $11.9 million or 46 percent, was from the "Other farms". This again indicates relative economic importance of the "abnormal" farms. In NM-2, 49 percent of the total income was from "Other farms", and in NM-1, 37 percent. In the other CPA's only a very small part of the income was from "Other" farms. The average income for farms over $2,500 was $79,950; the highest average was CO-7, with about $145,000. The lowest averages were in NM-1 and NM-2.

AGRICULTURAL INTENSITY

The fact that relatively little of the land in the CPA's is in private ownership, that a relatively small proportion of the farm land is cropland, and that there is a relatively low concentration of high value crops, all emphasize the fact that the Rocky Mountain Region's agriculture is very extensive in nature -- except in CO-7. One measure of intensity is the ratio of farm sales to land area.

Table 17 Gross Farm Sales, 1974

| Coal production areas | Income From All Farms | | | Farms over $2,500 | Other farms 2/ |
|---|---|---|---|---|---|
| | Livestock | Crops 1/ | Total | | |
| | $1,000 | | | | |
| Arizona-1 | 24,514 | 1,578 | 26,091 | 14,159 | 11,932 |
| Colorado-1 | 12,750 | 5,930 | 18,680 | 18,632 | 48 |
| Colorado-2 | 4,101 | 1,430 | 5,531 | 5,526 | 5 |
| Colorado-3 | 5,338 | 1,276 | 6,615 | 5,695 | 920 |
| Colorado-4 | 58,361 | 33,874 | 92,236 | 90,840 | 1,396 |
| Colorado-5 | 10,377 | 6,936 | 17,313 | 16,618 | 695 |
| Colorado-6 | 10,335 | 1,469 | 11,804 | 11,614 | 190 |
| Colorado-7 3/ | 555,386 | 170,448 | 725,834 | 724,571 | 1,263 |
| New Mexico-1 | 2,888 | 2,697 | 5,585 | 3,517 | 2,068 |
| New Mexico-2 | 6,383 | 1,296 | 7,679 | 3,883 | 3,796 |
| New Mexico-3 | 10,869 | 1,084 | 11,953 | 11,840 | 113 |
| New Mexico-4 | 5,328 | 2,294 | 7,623 | 7,428 | 195 |
| Utah-1 | 14,955 | 3,127 | 18,082 | 17,661 | 421 |
| Utah-2 | 4,266 | 659 | 4,925 | 4,754 | 171 |
| Utah-3 | 6,028 | 1,067 | 7,096 | 6,192 | 904 |
| Total | 731,879 | 235,165 | 967,047 | 942,930 | 24,117 |
| Weld County | 489,696 | 111,621 | 601,317 | 600,873 | 444 |
| Totals excluding Weld County: | | | | | |
| CO-7 | 65,690 | 58,827 | 124,517 | 123,698 | 819 |
| Region | 242,183 | 123,544 | 365,730 | 342,057 | 23,673 |

1/ Includes small amounts of forest products, nursery, and greenhouse products sold from farms.

2/ Includes farms with less than $2,500 gross sales and "abnormal" farms (see text).

3/ Includes Weld County, Colorado.

Compiled from U.S. Census of Agriculture, Volume 1. (26)

The average sales per acre for the CPA's was $10.66, the lowest was $0.67 in UT-2. (Table 18) 7/

Another measure is the ratio of farm numbers to land area, expressed as farms per township. Again, CO-7 is by far the most intensive — 15.5 per township. CO-5 and CO-4 are next with 5.4 and 5.5, respectively. AZ-1 is least with an average of 0.3.

A third measure is livestock numbers per unit of land area, expressed as animal units per 1,000 acres. CO-7 is the most intensive, 70.9 animal units per 1,000 acres and CO-2 is the next with 26.0. UT-2 and AZ-1 are the least intensive in livestock.

COMPETITION FOR RESOURCES

Except for CO-7, the CPA's are characterized by the extensive nature of their agriculture and the sparse population. Except for the irrigated farms, and a few places where dry land wheat is grown, the land is used mostly for grazing. The carrying capacity of most rangeland is relatively low, especially in UT-2, AZ-1, NM-1, and NM-2, as suggested by the data in Table 18. In addition, the Indian tribes, because of the quality of their land and their administrative structure, use their land mainly for grazing sheep and cattle in a very extensive manner.

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7/ The average for Weld County was $234 per acre. Without Weld County the average for CO-7 would be $2.56 per acre and the average for the region would be $4.15. (26)

Table 18 Selected Measures of Agricultural Intensity

| Coal production areas | 1974 Gross sales per acre of land area 1/ | Number of class 1-5 farms per township 1/ | Animal units per 1000 acres of land area 2/ |
|---|---|---|---|
| | -- dollars --- | --------- number ---------- | |
| Arizona-1 | 1.03 | 0.3 | 6.1 |
| Colorado-1 | 4.13 | 2.4 | 15.7 |
| Colorado-2 | 5.33 | 1.9 | 26.0 |
| Colorado-3 | 2.78 | 2.0 | 9.3 |
| Colorado-4 | 8.15 | 5.0 | 22.9 |
| Colorado-5 | 5.26 | 5.4 | 17.5 |
| Colorado-6 | 2.90 | 2.5 | 14.5 |
| Colorado-7 | 97.65 | 15.5 | 70.9 |
| New Mexico-1 | 1.59 | 1.3 | 6.2 |
| New Mexico-2 | 1.31 | 0.8 | 7.4 |
| New Mexico-3 | 4.96 | 1.9 | 15.7 |
| New Mexico-4 | 1.80 | 1.2 | 8.7 |
| Utah-1 | 3.60 | 3.1 | 11.8 |
| Utah-2 | 0.67 | 0.6 | 4.4 |
| Utah-3 | 2.47 | 2.4 | 12.7 |
| Region Average | 10.66 | 3.0 | 15.9 |

1/ A township is defined here as the land area equivalent to 36 sections or 23,040 acres.

2/ Animal units are: Milk cows=1.00; Other cows=0.80; Other cattle=0.50; Hogs=0.20; and Sheep=0.15.

Compiled from U.S. Census of Agriculture, Volume 1. (26)

Obviously, the amount of land disturbed per unit of coal production is directly related to the thickness of the seam to be mined. Data on seam thickness are used to estimate coal reserves per acre. CPA average surface mineable coal reserves in this region range from 7,200 tons per acre in UT-1 to 34,560 tons in CO-2. (13, 36) Figures on coal reserves per acre can be used to estimate the amount of land disturbed per unit of coal production. For each million tons of strippable coal reserves, land disturbance potential would range from 31.8 acres in CO-2 to 152.8 acres in UT-1.

Using some set of coal output projections, total land disturbance over some future period can be illustrated. For example, if cumulative RM coal production over the next 25 years were to reach 1.6 billion tons distributed as suggested by one projection 8/, about 118,000 acres would be disturbed. In addition, facilities for transporting and processing the coal would use about 25,000 acres. The maximum amount of land at risk would be equivalent to the total area underlain by surface mineable reserves. (Table 19)

Naturally, because of reclamation practices spurred by State and Federal laws, part of a cumulation of land disturbance by mining could be considered "reclaimed" by 2000 and some proportion of the agricultural land would be back in production. Nevertheless, the cumulative figure is useful as a rough measure of the maximum possible scale of land disturbance.

Therefore, for cumulative strip coal production of the above projected amount and distribution, the maximum possible farm land at risk in the region

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8/ This projection represents a summation of all the planned operations of the energy companies which expect to conduct mining operations in the area. (9) Since the plans referred to were all made before 1977, subsequent events obviously may cause considerable change in these plans.

Table 19 Estimated area underlain by coal reserves in the Rocky Mountains

| State | Type of reserves | | | Share of area underlain | | |
|---|---|---|---|---|---|---|
| | Surface 1/ mineable | Underground 2/ mineable | All | By surface 1/ reserves | By underground 2/ reserves | By all reserves |
| | acres | | | percent | | |
| Arizona | 19,770 | 0 | 19,770 | .03 | 0 | .03 |
| Colorado | 40,278 | 1,083,950 | 1,124,228 | .06 | 1.62 | 1.68 |
| New Mexico | 115,759 | 207,171 | 322,930 | .15 | .27 | .41 |
| Utah | 10,556 | 247,500 | 258,056 | .02 | .46 | .48 |
| RM 3/ | 186,363 | 1,538,621 | 1,724,984 | .07 | .57 | .64 |

1/ Mineable by surface mining methods, that is, strippable.

2/ Mineable only by underground methods at current technologies.

3/ Does not account for multiple beds, that is, estimates are made on the assumption that there is only a single seam present.

Sources: The Reserve Base of U.S. Coals by Sulfur Content (in two parts) 2. The Western States. U.S.B.M. Information Circular 8693. (13)

Strippable Reserves of Bituminous Coal and Lignite in the United States. U.S.B.M. Information Circular 8531. (36)

Note: This table was prepared by Virgil Whetzel.

would be equivalent to 41 farms of average size; the equivalent of 0.3 percent of the total farm land; or the equivalent of 0.16 percent of the total land area. 9/

COMPETITION FOR WATER

As shown by the above, even expanded strip mining for coal would have little effect, in the aggregate, on the amount of land available for agriculture. True, a number of farms or ranches would be disturbed, and some land would be taken out of production -- some permanently, without doubt -- but the total effect on the productive capacity of any CPA would be scarcely noticeable, if the land affected were average in quality and use.

However, if a particular mining operation disturbed irrigated land, the impact could be quite noticeable. Most of the irrigated land is used to produce food and forage, suggesting that it is important as a feed base for range livestock units. If irrigated land were to be removed from production, either temporarily or permanently, the effect would be to reduce the feed base. This, in turn, would put added pressure on the surrounding grazing land, which is already overgrazed in some areas. Livestock numbers could be reduced.

Yet, nearly all the strippable coal reserves are located at some distance from the irrigated land. Therefore, it is unlikely that much irrigated land will be physically disturbed. Nevertheless, competition for water

9/ "Land disturbed by mining" divided by average size of farm.

supplies between agriculture and mining or electric power plants might reduce the water available for irrigation, and livestock production.

The amount of water that might be required for coal development will vary with its use and point of use. In NM-1, the Four Corners Power Plant, a mine-mouth thermogenerator, has a water right for 40,000 acre feet annually for cooling. (3, p. 106) In the same CPA, a proposed coal gasification plant would use 10,360 acre feet annually for a plant with a capacity of 288 million cubic feet per day (MMCFD), or 15,000 acre feet for 410 MMCFD. (37) In AZ-1, the Black Mesa slurry pipeline, using about 3,440 acre feet of ground water, carries 4.8 million tons of coal annually from the Peabody Mine to the Southern California Edison Power Plant on the Colorado River in Nevada. (5) Near the same location, coal is shipped by unit train from the Peabody Mine; the quantity of water used in such an operation is negligible.

The net effect of future coal development on water supplies for irrigated agriculture will be dependent upon the location of new mines and the methods of processing and transporting the coal. In AZ-1, the effect of future coal development on irrigation would be negligible, because no irrigation is practiced or planned in the area where mining is taking place.

In NM-1, most of the land now irrigated is located in the valley of the San Juan River. Coal deposits do exist in the immediate vicinity; some may lie under the irrigated land. The Navajo Irrigation Project, under construction, will provide facilities to irrigate 110,000 acres

adjacent to the Utah International Mine. Direct competition between irrigation and mining is not expected because the coal beneath the irrigable land is considerably more than 90 feet below the surface, the likely maximum depth for profitable stripping in this area. Water for the proposed El Paso gasification plant in NM-1 would come from the San Juan River. In the preparation of the Environmental Impact Statement for the project, it was assumed that water for irrigation projects, present and proposed, would be unaffected in normal water years. (37)

In NM-2, the amount of irrigated land is less than 2,000 acres although the land that might be disturbed by mining by the year 2000 could be five times that figure. However, the location of the irrigated land in relation to the coal deposits is not available in sufficient detail to ascertain whether or not there would be any direct conflict for the use of the land. There are no new irrigation projects proposed in this area.

In CO-1, a new irrigation project, the Savery-Pothook, has been authorized and is now being proposed for construction. It will provide water for about 32,000 acres, of which only a little over half is in the CPA; nearly half is in Wyoming. The new land, added to that now irrigated in CO-1 would bring the total to about 100,000 acres. A substantial amount of strip mining is projected, but its exact location with respect to the irrigated land is not available.

GENERAL APPRAISAL

The effect of coal development on total agricultural production in the Rocky Mountain Region is expected to be negligible, especially when

viewed from a regional or national standpoint. However, the effect on the displaced farmers and ranchers would be severe, especially in the CPA's where the mines are located on Indian land, because on each reservation there are many Indian families who live on the land, and subsist by grazing sheep. In the case of the proposed El Paso gasification plant, it is estimated that 48 Navajo Indian families would be relocated over the life of the project. All of these families are now dependent on sheep grazing for a significant part of their livelihood. (37, p. 3-62) Moving such families would permanently alter their lifestyle, because there is no similar land available to which they could be moved. Many have a strong cultural or religious attachment to the particular place where their traditional homes are located.

In short, projected coal development in the Rocky Mountain Region poses no threat to national agricultural productive capacity. In competition for land and water resources on strictly economic terms, there is little doubt that coal development will prove to be the more profitable way to use the resources. However, on non-economic grounds, questions do arise concerning the desirability of opening new mines and building new power plants. Attempting to resolve these questions, though, is beyond the scope of this report.

# WATER

by
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## THE RIVER BASINS

The Rocky Mountain region contains portions of six distinct river basins including the Great Basin, the Upper Colorado River Basin, the Lower Colorado River Basin, the Missouri River Basin, the Arkansas River Basin, and the Rio Grande Basin. These basins are shown in Figure 11. The headwaters of rivers such as the Colorado, Arkansas, and Rio-Grande are contained in the region. However, the geographic location of major coal deposits and water supplies do not necessarily coincide. Since the primary concern is, eventually, to assess the availability of water to provide for energy needs, the water resource profile will be restricted to those river basins which will most likely provide the water necessary for future increases in coal production and use. The basins which appear to be most relevant to future coal production are the Colorado River Basin, the Great Basin, the Missouri Basin and the Rio Grande Basin. A brief description of each basin and the relevance to regional coal production follows.

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Gray, Griffen and Sparling are Associate Professor, Research Assistant, and Assistant Professor, respectively, Department of Economics, Colorado State University. They prepared this section, "Water," under the title: "Water Resource Base in the Rocky Mountain Region."

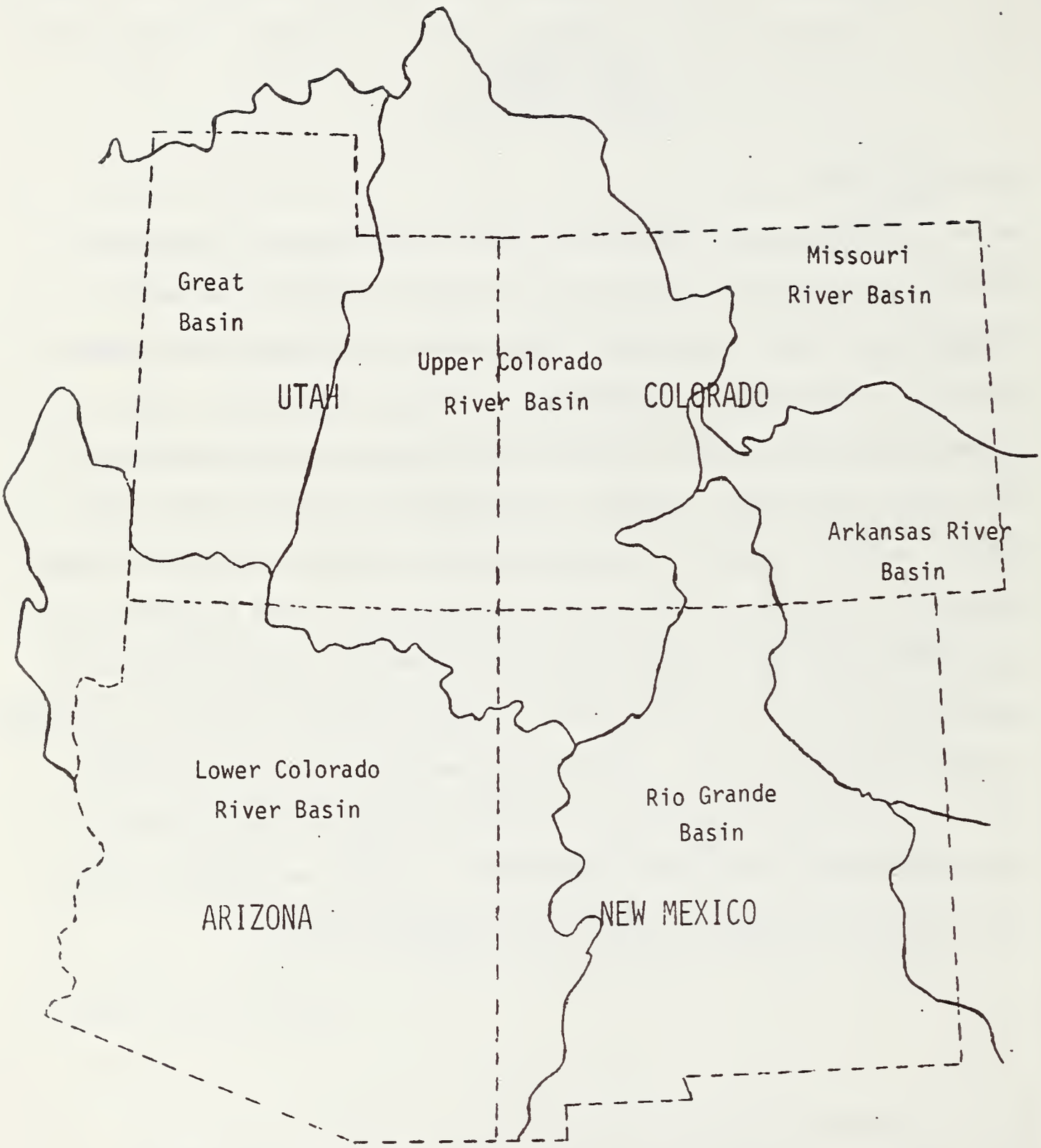


FIGURE 11

Major River Basins of the Rocky Mountain States

Colorado River Basin

The Colorado River Basin includes portions of all four of the Rocky Mountain states in addition to parts of Nevada and Wyoming. This Basin encompasses a land area greater than the combined area of New Mexico and Arizona, the nation's fifth and sixth largest states. This basin is clearly the most important of the Rocky Mountain Region. The basin, under the Colorado River Compact (1922) is divided into two segments, the upper and lower basins. Lee Ferry, a point on the Colorado a few miles into Arizona, is the designated division between the Upper and Lower Colorado River Basins. All data of the following sections will be presented according to this separation.

The Upper Colorado includes the Wyoming and Colorado portions of the Colorado River Basin, part of Utah, and small areas within Arizona and New Mexico. Major coal mining and conversion is anticipated throughout this region. The major coal deposits of the Upper Colorado Basin are the medium to highly volatile bituminous coal deposits in northeastern and central Utah and northwestern and southwestern Colorado. In addition, the Upper Colorado Basin contains deposits of subbituminous and bituminous coal in northeastern New Mexico.

The Lower Colorado Basin, some 135,900 square miles, contains most of Arizona and parts of Nevada, New Mexico, and Utah. The basin includes 5,200 square miles which drain directly into Mexico. The major coal production of the Lower Colorado Basin is to be found in the Basin's northeast portion where deposits of subbituminous coal are located.

The Great Basin

The Great Basin, largely a collection of basins which are closed with respect to surface water flows, includes most of Nevada, the western half of Utah, and small portions of the states of Wyoming and Idaho. Within the Rocky Mountain region, only the southeastern portion of the Great Basin, in south-central Utah, is expected to contain significant future increases in coal production. The coal deposits in the Great Basin are of the medium- to high-volatile bituminous coal type.

The Missouri River Basin

The only portion of the Missouri River Basin contained in the Rocky Mountain region is in northeastern quadrant of Colorado. The portion of the Missouri River Basin drained by the North Platte River possesses significant deposits of medium- and high-volatile subbituminous and bituminous coal available for future increased mining activity.

The Rio Grande Basin

The Rio Grande has its headwaters in Colorado and drains most of new Mexico and parts of Texas. Only a slight portion of this basin overlies a substantial coal deposit. Data availability prohibits delineation of the Rio Grande Basin into a region which accurately reflects the nature of water use and supplies in this small coal bearing region. Therefore, hydrologic consideration of any portion of the Rio Grande Basin is omitted from the following text. The effect of this omission is small.

Thus, four major basins appear to contain the areas with potential for rapid increases in coal production in the Rocky Mountain region. These four basins have been further disaggregated into eight separate subbasins, a disaggregation dictated largely by the available data on water supplies, present use, and projected future use. Three of these subbasins, the Green River, the Upper Colorado River and the San Juan are parts of the Upper Colorado Basin. Three of them, the Lower Colorado River, the Little Colorado River and the Gila River subbasins are parts of the Lower Colorado River Basin. The Great Basin contains the seventh subbasin, the Sevier Lake basin, and the Missouri River Basin houses the eighth subbasin, that of the North Platte River.

Within the Lower Colorado River Basin, the Little Colorado subbasin is currently of primary importance as a source of water. However, the two remaining subbasins will be significantly impacted by future energy development, and this warrants their inclusion. The Sevier Lake Subregion is a closed basin within the Great Basin and encompasses potential coal producing areas. As previously indicated, the North Platte is the relevant subbasin of the Missouri River Basin, and, therefore, it forms the eighth and final subregion. Only that part of the North Platte which lies in the State of Colorado is considered, and this part corresponds to Jackson County. The subbasins are shown in Figure 12.

The following discussion and presentation of data on water supplies, current depletions by use, and projections of future use are consistent with this subbasin disaggregation.

FIGURE 12.

Subbasins in the Rocky Mountain States

SURFACE WATER SUPPLIES

Mean undepleted surface water supplies for the six subregions of the Colorado River Basin are presented in Table 20. These quantities represent the average annual streamflow which would exist if man were to use no water in the Colorado River Basin.

Table 20--Surface water supplies of the Colorado River basin

| Subregion | Mean Undepleted Supplies 1,000 Acre-feet |
|---|---|
| Green | 5,460 |
| Upper Colorado | 6,806 |
| San Juan | 2,606 |
| Total | 14,872 |
| Lower Colorado (tributaries) | 900 |
| Little Colorado | 420 |
| Gila | 1,809 |
| Total | 3,129 |
| Colorado River Basin Total | 18,001 |

(16, pp.73, 88, 94), (25, p.59)

Of the more than 18 million acre-feet of annual water supplies in the entire basin, 14.9 million acre-feet originate in the upper basin. This amounts to 83 percent of the total water supply and illustrates the dependency of lower basin users on upper basin supplies.

In assessing the availability of water, Table 20 suffers from several deficiencies. In terms of location, the supplies of a subregion are obviously not uniformly available throughout the subregion. Secondly, seasonal variations in streamflow serve to decrease the amount of water which is constantly available. In critical years rainfall may be significantly below average, thus creating severe reductions in water supplies.

In the Sevier Lake Subregion average annual undepleted surface water supplies have been estimated to be 912,000 acre feet. (11, p.56) Of course the same deficiencies apply to this figure as those cited with respect to Table 20.

In the North Platte River Subregion, undepleted water supplies are approximately 600,000 acre-feet per year. (7, p.3.3)

Present Use

Table 21 identifies water depletions by sector for the eight subregions under consideration. With the exception of the North Platte River Subregion these quantities represent the level of depletions under 1965 normalized conditions; for the North Platte, the data are representative of 1970. The depletions indicated in Table 21 refer to groundwater and surface water depletions.

There are several peculiarities in Table 21 and some following tables. These peculiarities, stemming from the data sources, should be identified before proceeding with a discussion of present water use. In the Livestock column, only depletions for the Upper Colorado River Basin are identified;

Table 21--Depletion by type and basin in 1965

| Region and/or subregion | | Mineral and Industrial | Thermal Electric | Minerals | Fish and Wildlife | Recreation | Irrigation | Evaporation | Livestock | Net transfer | Other | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1,000 acre feet | | | | | | | | | | |
| Upper Colorado | Green | 7.9 | 6.3 | 17.2 | 8.0 | .5 | 818.4 | 67.0 | 13.3 | 120.9 | 0 | 1059.5 |
| | Upper Colorado | 12.3 | 1.6 | 11.9 | 1.3 | .5 | 931.6 | 0 | 11.2 | 426.9 | 0 | 1397.3 |
| | San Juan | 7.2 | 15.3 | 4.6 | 2.4 | .3 | 377.8 | 576.0 | 10.4 | -.1 | 0 | 993.9 |
| | Total | 27.4 | 23.3 | 33.7 | 11.7 | 1.3 | 2127.8 | 643.0 | 34.9 | 547.7 | 0 | 3450.7 |
| Lower Colorado | Lower Colorado | 48.2 | 2.8 | 2.6 | 100.0 | 1.1 | 1107.1 | 32.3 | --- | 1.3 | 0 | 1295.4 |
| | Little Colorado | 8.8 | .8 | .6 | 4.3 | .5 | 58.6 | 39.4 | --- | 15.0 | 0 | 128.0 |
| | Gila | 140.9 | 6.0 | 48.3 | 6.0 | 2.0 | 4059.8 | 158.7 | --- | -15.0 | 0 | 4406.7 |
| | Main Team | 0 | 0 | 0 | 0 | 0 | 0 | 1200.0 | 0 | 5000.0 | 1310.0 | 7510.0 |
| | Total | 197.9 | 9.6 | 51.5 | 110.3 | 3.6 | 5225.5 | 1430.4 | --- | 5001.3 | 0 | 13340.1 |
| Sevier Lake | | 7.0 | 0 | 1.0 | 55.0 | 1.0 | 600.0 | 70.0 | --- | -9.1 | 237.0 | 961.9 |
| Colorado | North Platte (1970) | --- | --- | --- | --- | --- | 108.0 | --- | --- | 22.0 | 2.0 | 132.0 |
| | Total | 232.3 | 32.8 | 86.2 | 177.0 | 5.9 | 8061.3 | 2143.4 | 39.4 | 5561.9 | 1549.0 | 17884.7 |

Sources: (7), (11), (16), (25).

in the other subregions the use of water for livestock watering (mainly evaporation) is included in the Evaporation Column.

As another complication, evaporation on the main stem reservoirs of the Upper Colorado River is allocated to the three subregions in accordance with the location of each reservoir, but on the Lower Colorado this has not been done. Because of this and the annual transfer of five million acre-feet of water to California, a row representing the main stem of the Lower Colorado River has been introduced into the table. It will also be noted that the data for the North Platte Subregion are not broken down as finely as the data for other subregions, necessitating the insertion of an "other" column. Finally, the items just mentioned are undoubtedly not the only points where data sources lack harmony. Methods of data collection and treatment will vary between studies. Recognizing these imperfections, the data presented here are approximations.

The majority (62 percent) of the Upper Colorado regional depletions of 3.45 million acre-feet are for irrigation. In contrast, only 40 percent of the Lower Colorado Region's total depletions are identified as irrigation, but this is due to the disproportionate transfer of five million acre-feet to California. If the transfer to California is disregarded, irrigation would account for 63 percent of total water depletions. Interestingly enough, irrigation depletions in the Sevier Lake Subregion amount to 62 percent of the total in that basin. In Colorado's North Platte, irrigation accounts for 82 percent of the total, indicating the agricultural base of that region.

The "Other" column indicates 1.31 million acre-feet of depletions for the Lower Colorado Main Stem. This is composed of system spills and channel losses. (16, p. 45) "Other" for the Sevier Lake Subregion refers to wet meadows, unmanaged fish and wildlife, and associated wetlands. (11, p. 88)

Although it is not explicitly shown in Table 21, total depletions for the Colorado River Basin are 16,790,800 acre-feet per year. Of this amount, 13,340,100 acre-feet, or nearly 80 percent, is used in the Lower Colorado Region. Recall that 83 percent of the total Colorado River Basin surface water supply originates in the upper basin. Therefore, although the major proportion of supplies comes from the upper basin, the major consumption occurs in the lower basin.

In aggregate, the eight subregions consume 17.9 million acre-feet of water as exhibited in Table 21. However, not all of these depletions are attributable to the Rocky Mountain States. Large parts of two subregions lie in Nevada or Wyoming. (Figure 12) Therefore, it is useful to break down water depletions according to states rather than basins, a task accomplished in Table 22.

Table 22 is essentially the same as Table 21 with two exceptions. First, the Upper and Lower Colorado regional depletions are presented according to states instead of subregions, while the Sevier Lake Subregion (Utah) and the North Platte River Subregion (Colorado) remain unchanged. Second, the figures for the Upper Colorado Region have been updated as a result of some more recent data available on a state basis. Comparing Table 21

Table 22--Annual depletion by type and state

| Region | State | Mineral and Industrial | Thermal Electric | Minerals | Fish and Wildlife | Recreation | Irrigation | Evaporation | Livestock | Net transfer | Other | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1,000 acre feet | | | | | | | | | | |
| Upper Colorado (1974-76) | Arizona | 3.0 | 12.0 | 0 | 0 | 0 | 10.0 | 0 | 0 | 0 | 0 | 25.0 |
| | Colorado | 18.0 | 9.0 | 17.0 | 3.2 | .8 | 1255.0 | 269.0 | 21.0 | 504.0 | 0 | 2097.0 |
| | New Mexico | 8.0 | 25.0 | 4.0 | 4.2 | 1.1 | 90.7 | 58.0 | 5.0 | 136.0 | 0 | 332.0 |
| | Utah | 6.0 | 1.0 | 9.0 | 23.5 | .9 | 538.6 | 120.0 | 6.0 | 130.0 | 0 | 835.0 |
| | Wyoming | 3.0 | 3.0 | 18.0 | 5.5 | 10.9 | 264.6 | 73.0 | 21.0 | 10.0 | 0 | 409.0 |
| | Total | 38.0 | 50.0 | 48.0 | 36.4 | 13.7 | 2158.9 | 520.0 | 53.0 | 780.0 | 0 | 3698.0 |
| Lower Colorado (1965) | Arizona | 161.6 | 6.8 | 50.0 | 79.6 | 2.7 | 4913.4 | 202.9 | ---- | ---- | 0 | 5417.0 |
| | Nevada | 30.3 | 2.8 | .6 | 30.0 | .8 | 174.3 | 12.1 | ---- | ---- | 0 | 250.9 |
| | New Mexico | 3.6 | 0 | .9 | .7 | .1 | 71.6 | 12.0 | ---- | ---- | 0 | 88.9 |
| | Utah | 2.4 | 0 | 0 | 0 | 0 | 66.2 | 3.4 | ---- | 1.3 | 0 | 73.3 |
| | Main Stem | 0 | 0 | 0 | 0 | 0 | 0 | 1200.0 | 0 | 5000.0 | 1310.0 | 7510.0 |
| | Total | 197.9 | 9.6 | 51.5 | 110.0 | 3.6 | 5225.5 | 1430.4 | 0 | 5001.3 | 1310.0 | 13340.1 |
| Sevier Lake | Utah (1965) | 7.0 | 0 | 1.0 | 55.0 | 1.0 | 600.0 | 70.0 | ---- | -9.1 | 237.0 | 961.9 |
| North Platte | Colorado (1970) | ---- | ---- | ---- | ---- | ---- | 108.0 | ---- | ---- | 22.0 | 2.0 | 132.0 |
| All above regions | Arizona | 164.6 | 18.8 | 50.0 | 79.6 | 2.7 | 4923.4 | 202.9 | 0 | 0 | 0 | 5442.0 |
| | Colorado | 18.0 | 9.0 | 17.0 | 3.2 | .8 | 1363.0 | 269.0 | 21.0 | 526.0 | 2.0 | 2229.0 |
| | New Mexico | 11.6 | 25.0 | 4.9 | 4.9 | 1.2 | 162.3 | 70.0 | 5.0 | 136.0 | 0 | 420.9 |
| | Utah | 15.4 | 1.0 | 10.0 | 78.5 | 1.9 | 1204.8 | 193.3 | 6.0 | 122.2 | 237.0 | 1870.2 |
| | Lower Main Stem | 0 | 0 | 0 | 0 | 0 | 0 | 1200.0 | 0 | 5000.0 | 1310.0 | 7510.0 |
| | Total | 209.6 | 53.8 | 81.9 | 166.2 | 6.6 | 7653.5 | 1935.3 | 32.0 | 5784.2 | 1549.0 | 17472.1 |

Sources: (7), (11), (16), (21), (22), (25).

and 22, the updated data have resulted in a total increased depletion of 247,300 acre-feet per year in the upper basin.

The lower rows of Table 22 show individual state depletion totals for the river basins under consideration and the total depletions of the Rocky Mountain States. Nevada and Wyoming are excluded from this total, thereby yielding a total which is slightly less than that of Table 21.

Projected Use

Tables 23 and 24 illustrate present and projected water depletions by basin and state, respectively, for 1965, 1980, 2000, and 2020. Irrigation is the only specific type of use identified in these tables, and, as the titles point out, neither table includes projected changes in the depletions due to energy related activities such as thermal power and mining.

Projections for the North Platte Subregion are unavailable at this time, but the present level of depletions can be expected to continue without diminishing. The most probable situation is that total depletions for this subregion will increase. Note that the projected totals of Tables 23 and 24 do not include any depletions for the North Platte River Subregion. This means that such totals are underestimates and are therefore designated by a "+."

Tables 23 and 24 indicate that depletion levels will experience general increases during the future with some exceptions in the Lower Colorado Region. The reason for declining depletions in this region is the

TABLE 23.—PRESENT AND PROJECTED ANNUAL DEPLETIONS by TYPE AND BASIN, EXCLUDING CHANGES IN ENERGY NEEDS

| Region and/or Subregion | 1965 | | | 1980 | | | 2000 | | | 2020 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Irrigation | Other | Total | Irrigation | Other | Total | Irrigation | Other | Total | Irrigation | Other | Total |
| | 1,000 acre feet | | | | | | | | | | | |
| Upper Colorado — Green | 818.4 | 241.1 | 1,059.5 | 935.4 | 423.2 | 1,358.6 | 1,197.5 | 602.7 | 1,800.2 | 1,253.3 | 658.0 | 1,911.3 |
| Upper Colorado — Upper Colorado | 931.6 | 465.7 | 1,397.3 | 1,007.8 | 729.9 | 1,737.7 | 1,184.5 | 971.7 | 2,156.2 | 1,166.5 | 991.1 | 2,157.6 |
| Upper Colorado — San Juan | 377.8 | 616.1 | 993.9 | 610.5 | 809.0 | 1,419.5 | 882.4 | 825.2 | 1,707.6 | 877.0 | 854.3 | 1,731.3 |
| Upper Colorado — Total | 2,127.8 | 1,322.9 | 3,450.7 | 2,553.7 | 1,962.1 | 4,515.8 | 3,264.4 | 2,399.6 | 5,664.0 | 3,296.8 | 2,503.4 | 5,800.2 |
| Lower Colorado — Lower Colorado | 1,107.1 | 188.3 | 1,295.4 | 1,402.0 | 294.3 | 1,696.3 | 1,365.0 | 484.5 | 1,849.5 | 1,456.0 | 660.2 | 2,124.2 |
| Lower Colorado — Little Colorado | 58.6 | 69.4 | 128.0 | 72.0 | 83.5 | 155.5 | 72.0 | 102.1 | 174.1 | 72.0 | 129.5 | 201.5 |
| Lower Colorado — Gila | 4,059.8 | 346.9 | 4,406.7 | 4,492.0 | 476.3 | 4,968.3 | 3,875.0 | 725.3 | 4,600.3 | 3,853.0 | 1,200.0 | 5,053.0 |
| Lower Colorado — Main Stem | 0 | 7,510.0 | 7,510.0 | 0 | 6,510.0 | 6,510.0 | 0 | 6,140.0 | 6,140.0 | 0 | 6,140.0 | 6,140.0 |
| Lower Colorado — Total | 5,225.5 | 8,114.6 | 13,340.1 | 5,966.0 | 7,364.1 | 13,330.1 | 5,312.0 | 7,451.9 | 12,763.9 | 5,381.0 | 8,137.7 | 13,518.7 |
| Sevier Lake | 600.0 | 361.9 | 961.9 | 618.0 | 349.9 | 967.9 | 663.0 | 344.9 | 1,007.9 | 710.0 | 346.9 | 1,056.9 |
| Colorado North Platte (1970) | 108.0 | 24.0 | 132.0 | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Total | 8,061.3 | 9,823.4 | 17,884.7 | 9,137.7+ | 9,676.1+ | 18,813.8+ | 9,239.4+ | 10,196.4+ | 19,435.8+ | 9,387.8+ | 10,988.0+ | 20,375.8+ |

Sources: (11), (16), (21), (25).

Table 24. Present and projected annual depletions by type and state excluding changes in energy needs

| Region | State | 1965 | | | 1980 | | | 2000 | | | 2020 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Irrigation | Other | Total | Irrigation | Other | Total | Irrigation | Other | Total | Irrigation | Other | Total |
| | | 1,000 acre feet | | | | | | | | | | | |
| Upper Colorado (1974-76) | Arizona | 10.0 | 15.0 | 25.0 | 10.0 | 40.0 | 50.0 | 10.0 | 40.0 | 50.0 | 10.0 | 40.0 | 50.0 |
| | Colorado | 1,255.0 | 842.0 | 2,097.0 | 1,391.0 | 1,045.0 | 2,436.1 | 1,778.2 | 3,077.9 | 3,077.9 | 1,754.5 | 1,327.2 | 3,081.7 |
| | New Mexico | 90.7 | 241.3 | 332.0 | 245.0 | 221.5 | 466.5 | 411.0 | 228.3 | 639.3 | 411.0 | 244.6 | 655.6 |
| | Utah | 538.6 | 296.4 | 835.0 | 576.6 | 358.0 | 934.6 | 660.6 | 440.0 | 1,104.6 | 695.2 | 462.0 | 1,157.2 |
| | Wyoming | 264.6 | 144.4 | 409.0 | 334.0 | 187.1 | 521.1 | 407.0 | 274.7 | 681.7 | 427.1 | 314.1 | 741.2 |
| | Total | 2,158.9 | 1,539.1 | 3,698.0 | 2,556.7 | 1,851.6 | 4,408.3 | 3,266.8 | 2,286.7 | 5,553.5 | 3,297.8 | 2,387.0 | 5,685.7 |
| Lower Colorado | Arizona | 4,913.4 | 503.6 | 5,417.0 | 5,596.0 | 643.6 | 6,239.6 | 4,937.0 | 913.3 | 5,805.3 | 5,011.0 | 1,423.4 | 6,434.4 |
| | Nevada | 174.3 | 76.6 | 250.9 | 193.0 | 159.9 | 352.9 | 185.0 | 328.8 | 513.8 | 180.0 | 484.6 | 664.6 |
| | New Mexico | 71.6 | 17.3 | 88.9 | 99.0 | 27.4 | 126.4 | 110.0 | 45.5 | 155.5 | 101.0 | 63.7 | 164.7 |
| | Utah | 66.2 | 7.1 | 73.3 | 78.0 | 23.2 | 101.2 | 80.0 | 24.2 | 104.2 | 89.0 | 26.0 | 115.0 |
| | Main Stem | 0 | 7,510.0 | 7,510.0 | 0 | 6,510.0 | 6,510.0 | 0 | 6,140.0 | 6,140.0 | 0 | 6,140.0 | 6,140.0 |
| | Total | 5,225.5 | 8,114.6 | 13,340.1 | 5,966.0 | 7,364.1 | 13,330.1 | 5,312.0 | 7,451.8 | 12,763.8 | 5,381.0 | 8,137.7 | 13,518.7 |
| Sevier Lake | Utah | 600.0 | 361.9 | 961.9 | 618.0 | 349.9 | 967.9 | 663.0 | 344.9 | 1,007.9 | 710.0 | 346.9 | 1,056.9 |
| North Platte | Colorado (1970) | 108.0 | 24.0 | 132.0 | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| All above regions | Arizona | 4,923.4 | 518.6 | 5,442.0 | 5,606.0 | 683.6 | 6,289.6 | 4,947.0 | 953.3 | 5,900.0 | 5,021.0 | 1,463.4 | 6,484.4 |
| | Colorado | 1,363.0 | 866.0 | 2,229.0 | 1,391.1+ | 1,045.0+ | 2,436.1+ | 1,778.2+ | 1,229.7+ | 3,007.9+ | 1,754.5+ | 1,327.2+ | 3,081.7+ |
| | New Mexico | 162.3 | 258.6 | 420.9 | 344.0 | 248.9 | 592.9 | 521.0 | 273.8 | 974.8 | 512.0 | 308.3 | 820.3 |
| | Utah | 1,204.8 | 665.4 | 1,870.2 | 1,272.6 | 731.1 | 2,003.7 | 1,403.6 | 813.1 | 2,216.7 | 1,494.2 | 834.9 | 2,329.1 |
| | Lower Main Stem | 0 | 7,510.0 | 7,510.0 | 0 | 6,510.0 | 6,510.0 | 0 | 6,140.0 | 6,140.0 | 0 | 6,140.0 | 6,140.0 |
| | Total | 7,635.5 | 9,818.6 | 17,427.1 | 8,613.7+ | 9,218.6+ | 17,832.3+ | 8,649.8+ | 9,479.9+ | 18,129.7+ | 8,781.7+ | 10,073.8+ | 18,885.5+ |

Source: (7), (11), (16), (21), (25).

decreasing availability of water supplies due to increasing depletions in the Upper Colorado Region. As both tables illustrate, some of this pressure on lower basin users will be relaxed by decreasing the depletions of the Lower Colorado Main Stem. Although it is not shown in the tables, this decrease is to be accomplished by reducing transfers to California, system spills, and channel losses. (16, p. 45)

Future Availability

In order to assess the future availability of surface water for proposed energy development, it is necessary to combine the pictures of existing supplies and projected depletions that have been developed for the eight subregions. Since essentially three distinct river basins are being dealt with, the following estimates of future availability will appear in three parts. The first concerns the extremely important Colorado River Basin, and the latter two will consider the Sevier Lake Subregion and the North Platte River Subregion.

Present and projected average conditions in the Colorado River Basin are illustrated by Table 25. This table is a consolidation of Tables 20 and 24, and, as such, it represents depletions of the Colorado River Basin in relation to supplies. Institutional factors such as the Colorado River Compact, the Mexican Treaty, and the Upper Colorado River Basin Compact are neglected in Table 25.

The first row is the mean undepleted surface water supply of the entire Upper Colorado River Basin. The subsequent five rows give the individual state depletion levels within the Upper Colorado Region. When these

Table 25.—Projected annual summaries for the Colorado River Basin

| Supplies and depletions | Present | 1980 | 2000 | 2020 |
|---|---|---|---|---|
| | ----- | 1,000 acre-feet | ----- | |
| Upper Colorado Virgin Supply | 14,872 | 14,872 | 14,872 | 14,872 |
| Less: Arizona Depletions | 25 | 50 | 50 | 50 |
| Colorado Depletions | 2,097 | 2,436 | 3,078 | 3,082 |
| New Mexico Depletions | 332 | 467 | 639 | 656 |
| Utah Depletions | 835 | 935 | 1,105 | 1,157 |
| Wyoming Depletions | 409 | 521 | 682 | 741 |
| Residual Outflow (Lee Ferry) | 11,174 | 10,463 | 9,318 | 9,186 |
| Plus: Virgin Supply Originating in the Lower Colorado Basin | 3,129 | 3,129 | 3,129 | 3,129 |
| Lower Colorado Water Supply | 14,303 | 13,592 | 12,447 | 12,315 |
| Less: Arizona Depletions | 5,417 | 6,240 | 5,850 | 6,434 |
| Nevada Depletions | 251 | 353 | 514 | 665 |
| New Mexico Depletions | 89 | 126 | 156 | 165 |
| Utah Depletions | 72 | 101 | 104 | 115 |
| Main Stem Depletions | 7,510 | 6,510 | 6,140 | 6,140 |
| Residual Outflow | 964 | 262 | -317 | -1,204 |

depletions are subtracted from the supply, we have the residual outflow at the compact point, Lee Ferry. Adding surface water supplies originating within the Lower Colorado River Region yields the total surface water supply available to the lower basin states. Subtracting state depletions results in the remaining flow of the Colorado River into Mexico.

The most striking feature of Table 25 is the negative flows to Mexico in 2000 and 2020. Of course, this is impossible; yet, it does provide ample substantiation that the Colorado River will be unable to support future levels of development. Projected water deficits would have to be made up through the mining of ground-water supplies, improved efficiency in use of irrigation water, or more intensive use of return flows.

The present level of depletions in the Sevier Lake Subregion, for example, is already in excess of available surface water supplies, thus indicating the necessary present and future importance of groundwater usage in this subregion. (Table 26)

Table 26.—Projected annual summary for the Sevier Lake Subregion

| Item | Present | 1980 | 2000 | 2020 |
|---|---|---|---|---|
| | - - - - - - | 1,000 acre-feet | - - - - - - - | |
| Surface Water Supplies | 912 | 912 | 912 | 912 |
| Depletions | 962 | 968 | 1008 | 1057 |
| Residual | -50 | -56 | -96 | -145 |

Since projections for the North Platte River Subregion are unavailable, consideration is confined to the present relation of depletions to supplies. With present depletions of 132,000 acre-feet per year and a supply of 600,000 acre-feet, an excess annual supply of 468,000 acrefeet exists in this sub-region.

GROUNDWATER

The available data on water supplies, current use and projected water requirements indicate that one, or a combination, of several courses of action must be taken in regard to future water use in the Rocky Mountain States. The possibilities include, but are not necessarily limited to: 1) development of water saving technology in existing uses; 2) transfer of water rights from low valued to high valued uses; 3) transfers of water between basins; and 4) development of additional supplies from groundwater sources. It is to this latter possibility that discussion is directed in this section of the report.

Use of groundwater has both advantages and disadvantages when compared to utilization of surface water. On the negative side, groundwater can be depleted. In this sense, under certain circumstances, it is a stock or non-renewable resource. The critical factor here is the net recharge rate of the particular aquifer, where the recharge rate is the quantity of water, per unit of time, that enters the aquifer from alternative sources. When the recharge rate is less than the rate of withdrawal, that is, when the net recharge is negative, the resource is being mined. However, given favorable recharge conditions, utilization of groundwater

does have an important advantage over surface water in that a well can be drilled at almost any location over the aquifer and will yield a dependable quantity and quality of water. Spatial limitations, extreme seasonal fluctuations in supply, and associated variations in quality may be much more prevalent in the use of surface water.

However, the certainty of supply suggested above may not be the case. The hidden or invisible nature of groundwater creates a handicap and requires extensive hydrologic and geologic study to assess the quantities of water available. In the absence of such studies, reliance on increased groundwater use as a source of supply is a tenuous endeavor. Uncertainty of supply is characteristic of this case in which overdevelopment, resulting in excessive pumping costs and dry wells, may occur. Further problems may be caused due to the interrelationship between surface and groundwater supplies. As groundwater supplies are depleted, surface water drawdown increases, as may drawdown in other aquifers.

Groundwater supplies generally have no direct habitat value and if surface-groundwater interrelationships are minor, groundwater can be developed exclusive of concern for losses of wildlife and aquatic ecosystems. However, if the interrelationship is substantial, indirect habitat values may be quite important. This interrelationship is variable depending upon the hydrologic and geologic conditions of the aquifer and proximate areas. These considerations are suggestive of the need for extensive study prior to groundwater development.

Finally, disruption by strip mining and land subsidence are other potential difficulties associated with groundwater development.

Appraising the groundwater supplies available for future development for use in energy or other alternatives is difficult. However, it is generally concluded that, in the Rocky Mountain region, additional development of groundwater will result in mining. Estimates of of groundwater availability in the region are not plentiful, and are particularly scarce for deep aquifers. The following discussion presents data available on groundwater supplies for the subbasins identified previously.

Table 27 lists the estimated amounts of groundwater stored in the upper 100 feet of underlying aquifers in the Upper and Lower Colorado Regions and the Sevier Lake Subregion. Realistically, these figures serve as upper bounds on the amount of groundwater available for use.

Table 27.—Estimated storage of recoverable groundwater in upper 100 feet of aquifer (saturated thickness)

| | 1000 acre-feet |
|---|---|
| Upper Colorado | 82,940,000 |
| Lower Colorado | 473,000,000 |
| Sevier Lake Subregion | 21,700,000 |
| Total | 577,640,000 |

Sources: (11, p. 48), (16, p. 18), (25, p. 21)

The groundwater supplies indicated in Table 27 are dispersed across large areas, and therefore their recovery and use may not be economical at the present time. Unfortunately, it is not feasible to calculate the amount of groundwater which can be economically recovered because variables such as location, availability and cost of surface water, type of use, and the costs of obtaining groundwater must be specifically considered.

Upper Colorado River Basin

At present, groundwater within the Upper Colorado River Basin is relatively undeveloped. In 1970, groundwater use amounted to only 2 percent of this region's total withdrawals and depletions. (20, p. C17) Of the 63,000 acre-feet of depletions from groundwater supplies, irrigation accounted for 52 percent; public supplies, 25 percent; domestic and livestock, 17 percent; and industry, 6 percent. (20, p. C17)

Recharge to aquifers in the Upper Colorado River Basin is estimated to be capable of supporting four million acre-feet of groundwater pumpage per year without reducing groundwater levels. (20, p. C1)

Lower Colorado River Basin

In sharp contrast to the Upper Colorado Basin, groundwater accounts for a large proportion of total withdrawals in the Lower Colorado Basin. Regionally, groundwater withdrawals constitute 61 percent of total withdrawals. (16, p. 31) Table 28 shows that the Gila Subregion is primarily responsible for this large groundwater use.

Table 28.—Annual water withdrawals of the Lower Colorado River Basin

| Subregion | Groundwater | Surface Water | Total Withdrawals |
|---|---|---|---|
| | 1,000 acre-feet | | |
| Lower Colorado | 525 | 1,896 | 2,420 |
| Little Colorado | 74 | 78 | 152 |
| Gila | 4,465 | 1,231 | 5,696 |
| Total | 5,064 | 3,204 | 8,268 |

Source: (16, p.31)

In the Gila Subregion 78 percent of water withdrawals is obtained from underground. Groundwater mining has been extensive in this subregion and has resulted in rapidly falling groundwater levels. In one valley the groundwater level declined an average of 13.8 feet per year from 1958 to 1967. (1, p. 12) In some smaller areas the situation has been worse.

For the 1970 level of development, an estimated 2.2 million acre-feet of groundwater was mined in the State of Arizona. (1, p. 9) Mined ground-groundwater for the Lower Colorado River Basin was estimated to be 2.5 million acre-feet during 1965. (16, p. 30) This is about one-half of the total groundwater withdrawals shown in Table 28.

Sevier Lake Subregion

Natural discharges, such as springs, total 328,000 acre-feet per year in the Sevier Lake Subregion, with 106,000 acre-feet being consumed at

the 1965 level of development. (11, pp. 56-57) This leaves 222,000 acre feet for increased future use. However, points of discharge are dispersed and this full development of available groundwater is rendered difficult.

Groundwater withdrawal from wells in the Sevier Lake Subregion amounts to 280,000 acre-feet per year which includes 17,000 acre-feet mined. (11, pp. 51-52)

Some final notes are in order concerning the capability of groundwater supplies to aid in the provision of water for the development of energy resources. The groundwater supplies discussed above lack the capability to support major localized development for extended periods. Therefore, although these groundwater resources may provide for short term alternative uses such as irrigation, they cannot be the sole water source for energy conversion facilities. Deep aquifers may be better suited to supply ground water directly for energy development, but the data limitations prohibit an evaluation of the full potential of these aquifers. Finally, because of surface-groundwater interrelationships, hydrologic studies should be performed to determine the localized impact of specific energy facilities.

WATER: CONCLUSIONS

We have seen that in all of the Rocky Mountain Region, with the exception of the North Platte River Basin, water is scarce under current demand conditions. Moreover, there are areas, such as Arizona, where growth of these demands has already resulted in mining of groundwater

supplies. If current growth trends continue, water will become more critically scarce in these areas, even without considering possible future use for coal exploitation. With current technology, large scale coal development will result in diversion of water from current uses, most likely from irrigated agriculture. If energy companies were to purchase large numbers of water rights in the Colorado River Basin, and actually exercised these rights, not only agriculture in the area but also the communities which service the agricultural sector could be drastically affected.

Some alternatives for reducing such potential impacts were considered, and fall into two basic categories: 1) those based on augmentation of known water supplies, and 2) those based on technological change to decrease the water requirements of various production processes. Potential new supplies are highly uncertain. These include discovery of major deep aquifers and weather modification. The second group of alternatives seems much more likely to have significant future effects. For example, water requirements of irrigated agriculture may be drastically reduced through sophisticated irrigation techniques. Another example is the use of dry tower cooling for electricity generation plants.

Finally, an important dimension of the water supply picture is the complex web of claims and rights to use Colorado River water. Rights to this water were allocated to several states in the 1922 Colorado River Compact. Since 1922, regional development patterns have resulted in a

far greater use of water in the lower reaches of the Colorado River than in the upper reaches, where most of the water originates. Continuing development in the Upper Colorado River Basin and the consequent exercising of water rights in that region may very likely result in inter-regional or inter-state legal disputes. Moreover, a recent U.S.Mexican treaty entitles Mexico to certain amounts of Colorado River water of a specified quality. These obligations have yet to be met and the burden of meeting them has yet to be allocated among the various American water users. These issues exist prior to consideration of the use of Colorado River water for energy conversion. Thus, the diversion of Colorado River water from irrigation to electricity generation further complicates an already complex problem.

In conclusion, the use of water for energy conversion is subject to constraints both of economic demand and of legal-political nature, both of which are subject to uncertainty: the demand constraint to technological uncertainty, and institutional constraints to the unpredictable nature of the political process. A subsequent report will more fully explore these uncertainties.

# APPENDIX

## A Supplement on Mining Costs

by

Melvin D. Skold

In the Mining Costs statement included as part of the Northern Great Plains Regional Report, analyses of mining costs were left unfinished. A procedure was advanced which provided estimates of mining costs among coal-producing areas. The procedure utilizes county f.o.b. strip mine coal prices (where available) and statistically estimates the functional relationship between stripping ratios and coal-producing area f.o.b. mine prices.

Review of the available literature revealed that mine size may also be a determinant of mining costs. It is anticipated, however, that most economies of size are reached for even the smallest of the mines being considered in the Western states. Consequently, the role of the size variable in effecting mining costs in the West may be negligible. Nevertheless, this hypothesis still remains to be tested. Unfortunately, however, no new data have been discovered to enable testing the size hypothesis.

In the previous report, a statistical relationship between the stripping ratio (cubic yards of overburden per ton of coal) and f.o.b. mine prices; mine f.o.b. prices serving as a proxy for costs. The base relation

$$P = 2.5384 + 0.3581\ R$$

$r = .9137$ P = f.o.b. mine price

$t_b = 5.028$ R = stripping ratio

was estimated. Again, securing of new data have not enabled an updating or further verification of this equation.

Since the base equation was fitted to U.S. data, adapting this equation to fit the Mountain States requires two adjustments. First, in the above

equation, the average stripping ratio was 13.1:1 and the stripping ratio varies from this in each of the four Mountain States. It would be expected that the b-value would reflect the absolute size of the stripping ratio as well as the relationship between the ratio and f.o.b. prices. Thus, the b-value (regression coefficient) is adjusted in each case as:[1/]

$$\frac{R_j(b)}{R} = b_j$$

where $R_j$ = average stripping ratio in the j-th state

$R$ = average stripping ratio in the base equation

$b$ = 0.3581, from the base equation

$b_j$ = b-value for the j-th state

The y-intercept or constant value is also based on the different data set. It reflects the overall level of f.o.b. prices and is 2.5384 in the base equation. The average price level varies between each state, however, and the state average f.o.b. mine price for 1972 (the year for which the base equation was fitted) is substituted for the constant figure. With these adjustments, a separate and unique equation is formed for each state as:

$$P_A = 3.38 + 0.2488\ R_A \text{ (Arizona)}$$

$$P_C = 4.10 + 0.3062\ R_C \text{ (Colorado)}$$

$$P_{NM} = 2.66 + 0.2624\ R_{NM} \text{ (New Mexico)}$$

State average f.o.b. mine prices are not available for Arizona and Utah;

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[1/] Data for the state average stripping ratios and the average stripping ratios within homogeneous coal-producing areas, discussed below, were estimated by Virgil Whetzel.

consequently, regional average prices are used. The f.o.b. mine price variation within states is determined by the differential between a homogeneous coal-producing area's stripping ratio and the state average stripping ratio. Thus, since Arizona has only one coal-producing area, the equation becomes:

AZ1: $P = 3.38 + (.2488)\ (\ 9.1 - 9.1) = \$3.38$

For the three coal producing areas in Colorado, the f.o.b. mine price estimates are:

CO1: $P = 4.10 + (.3062)\ (10.6 - 9.6) = \$4.41$
CO2: $P = 4.10 + (.3062)\ (\ 5.6 - 9.6) = \ 2.88$
CO4 $P = 4.10 + (.3062)\ (11.2 - 9.6) = \ 4.59$

And for New Mexico:

NM1: $P = 2.66 + (.2624)\ (\ 9.2 - 9.6) = \$2.56$
NM2: $P = 2.66 + (.2624)\ (12.8 - 9.6) = \ 3.50$

Finally, for Utah:

UT1: $P = 3.38 + (.2324)\ (\ 9.0 - 6.9) = \$3.87$
UT2: $P = 3.38 + (.2324)\ (\ 6.7 - 6.9) = \ 3.33$

Given these working estimates of f.o.b. mine prices by coal-producing area, the next requirement is to update these prices to reflect expected levels in future target years. Recall that the base equation was derived using 1972 data. Thus, the coal-producing area prices derived from the adjusted base equation represent 1972 levels.

Many alternatives exist for projecting coal prices and mining costs. One can follow the trend in a statistic such as the wholesale price for bituminous coal. Alternatively, the f.o.b. price for strip-mined coal could be projected. Since historical statistics on f.o.b. strip mine prices are not uniformly available among the states in question, it was decided to use the trend in wholesale coal prices for projections. During

the 1957-75 period, wholesale coal prices advanced an average of 11.7 percent per year (1967 = 100). It should be noted that the most significant increases have occurred since 1970.

Applying a linear trend to coal prices, we derive a price index of 308 for 1980 and 367 for 1985 (again, 1967 = 100). In 1972, the year to which our base equation applies, the wholesale price index for coal for the same base year stood at 193.8. Thus, 1980 prices are projected at 308 ÷ 193.8 = 1.589 times the 1972 price level. Adjusting the regional prices derived earlier for the Northern Great Plains region and above for the Mountain region we derive the prices for 1980 which appear in table 1. The projected prices for 1975 and 1985, also appearing in the tables, were computed following a similar procedure as described for calculating the adjustment coefficient for 1980.

The procedure for cost projections described above maintains the same relative prices between regions into the future as existed in 1972. It should be remembered that for interregional analysis it is the relative prices that are important. The absolute price levels may be important in comparing one solution with another; yet, it is likely the relative total costs of alternative solutions is as important as the exact cost level. Thus, this procedure may be valid to cost computations for interregional analysis, but may not be sound for analysis in which absolute levels of prices and costs are important pieces of information.

Table A.—Projected Coal Mining Costs (F.O.B. Mine Prices) by Coal Producing Area, Western States

| Region and State | Coal producing area | 1972 price estimate | Price projection for: 1975 | 1980 | 1985 |
|---|---|---|---|---|---|
| | | $/ton | $/ton | $/ton | $/ton |
| Northern Great Plains: | | | | | |
| Montana | MT1 | $ 2.21 | $ 2.84 | $ 3.51 | $ 4.18 |
| | MT2 | 2.38 | 3.06 | 3.78 | 4.50 |
| | MT3 | 3.18 | 4.09 | 5.05 | 6.01 |
| | MT4 | 1.87 | 2.40 | 2.97 | 3.54 |
| | MT5 | 2.06 | 2.65 | 3.27 | 3.89 |
| North Dakota | ND1 | 2.57 | 3.31 | 4.08 | 4.86 |
| | ND2 | 1.82 | 2.34 | 2.89 | 3.44 |
| | ND3 | 1.85 | 2.38 | 2.94 | 3.50 |
| South Dakota | SD1 | 14.00 | 18.00 | 22.25 | 26.47 |
| Wyoming | WY1 | 3.88 | 4.99 | 6.16 | 7.34 |
| | WY2 | 3.68 | 4.73 | 5.85 | 6.96 |
| | WY3 | 3.89 | 5.00 | 6.18 | 7.36 |
| | WY4 | 4.01 | 5.16 | 6.37 | 7.58 |
| Mountain States: | | | | | |
| Arizona | AR1 | 5.64 | 7.25 | 8.96 | 10.67 |
| Colorado | CO1 | 4.41 | 5.67 | 7.01 | 8.34 |
| | CO2 | 2.88 | 3.70 | 4.58 | 5.45 |
| | CO4 | 4.59 | 5.90 | 7.29 | 8.68 |
| New Mexico | NM1 | 2.56 | 3.29 | 4.07 | 4.84 |
| | NM2 | 3.50 | 4.50 | 5.56 | 6.62 |
| Utah | UT1 | 3.87 | 4.97 | 6.15 | 7.31 |
| | UT2 | 3.33 | 4.28 | 5.29 | 6.29 |

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